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(54) **SYSTEM FOR INTEGRATING A PLURALITY OF MODULES USING A POWER/DATA BACKBONE NETWORK**

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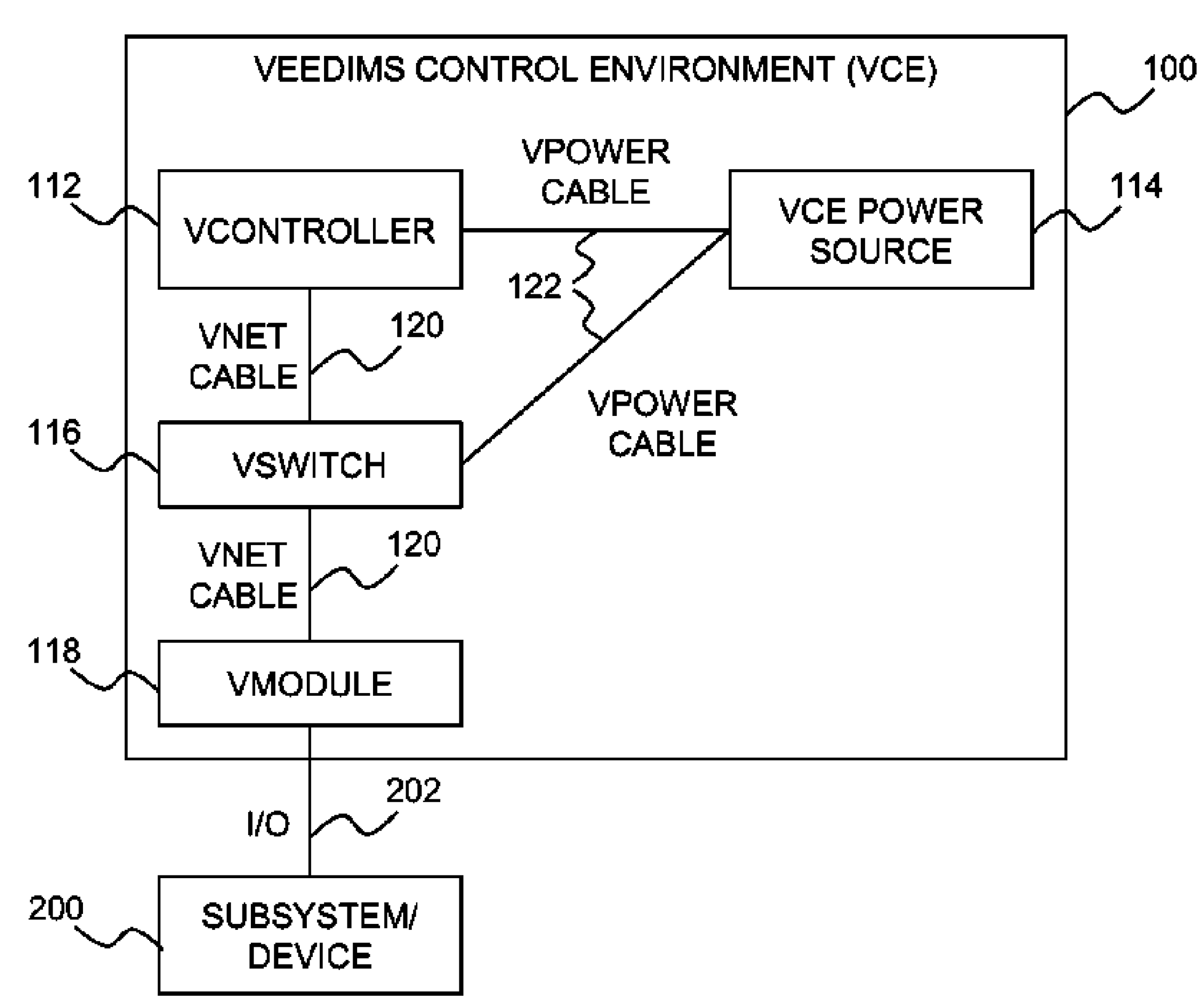
(57) **ABSTRACT**

A Virtual Electrical and Electronic Device Interface and Management System (VEEDIMS) support architecture is provided. In one example, the VEEDIMS support architecture includes a vehicle layer and a shop layer. The vehicle layer has a module and a controller positioned in a vehicle. The module is configured to couple to a device via an input/output (I/O) interface compatible with the device and configured to couple to the controller via a cable adapted to simultaneously carry bi-directional data and uni-directional power to the module. The shop layer is separate from the vehicle layer and has a browser configured to communicate with an HTTP server in the module and an analysis tool configured to receive and analyze event driven and time series data from the controller.

20 Claims, 10 Drawing Sheets



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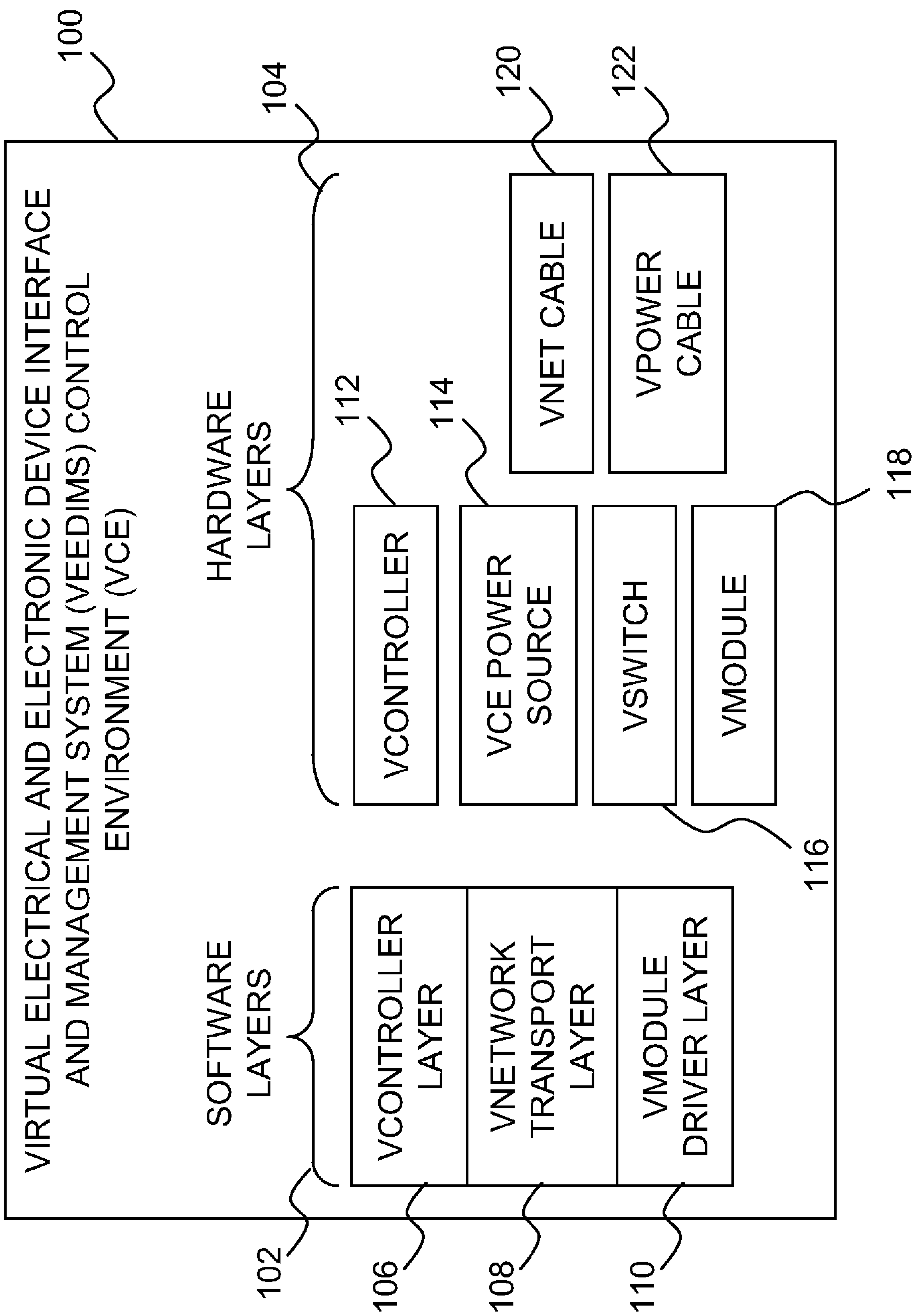

100
VIRTUAL ELECTRICAL AND ELECTRONIC DEVICE INTERFACE AND MANAGEMENT SYSTEM (VEEDIMS) CONTROL ENVIRONMENT (VCE)
SOFTWARE LAYERS
102
VCONTROLLER LAYER
106
VNETWORK TRANSPORT LAYER
108
VMODULE DRIVER LAYER
110
HARDWARE LAYERS
104
VCONTROLLER
112
VCE POWER SOURCE
114
VSWITCH
116
VMODULE
118
VNET CABLE
120
VPOWER CABLE
122

Fig. 1

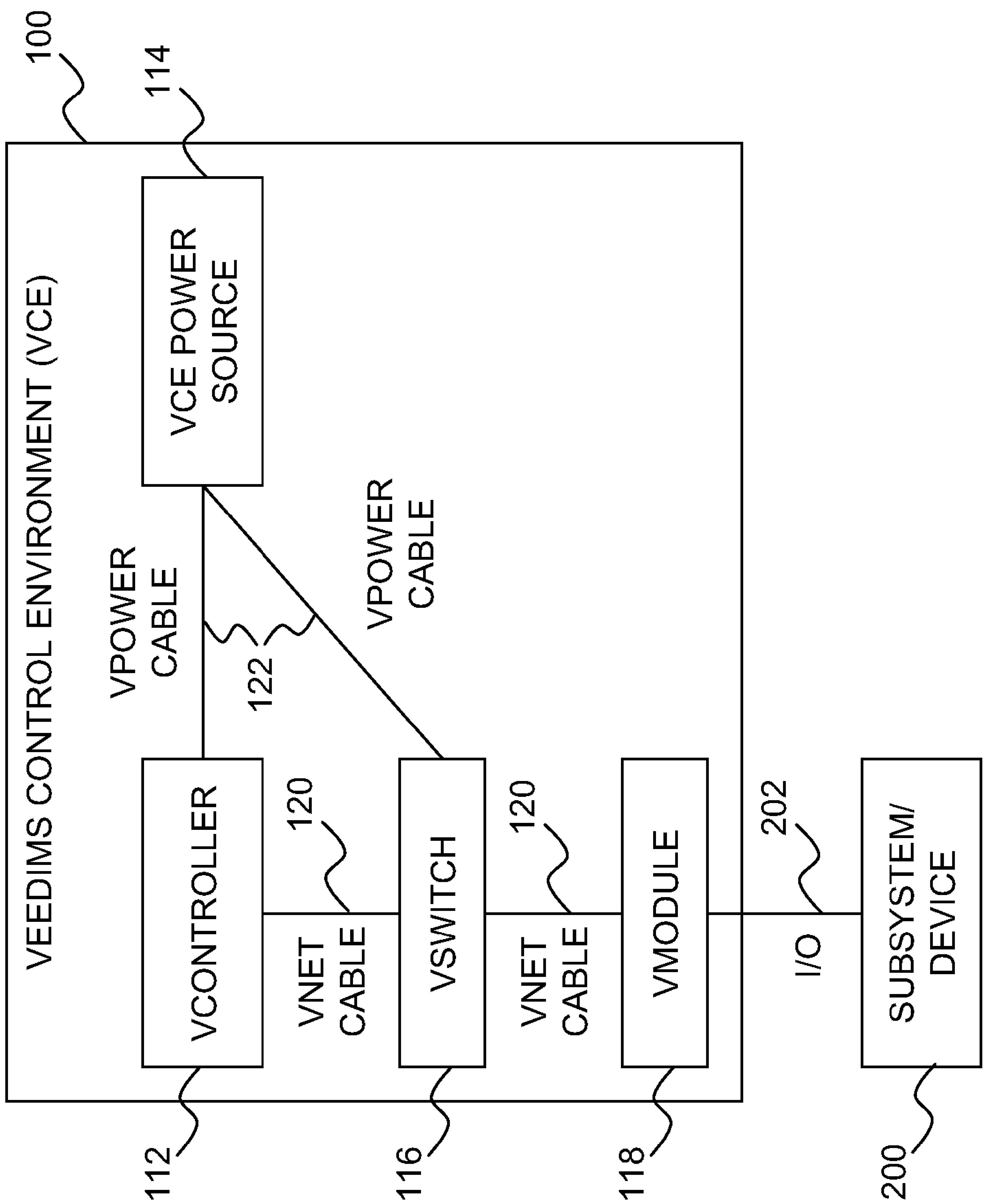

VEEDIMS CONTROL ENVIRONMENT (VCE)
100
VCE POWER SOURCE
114
VPOWER CABLE
VPOWER CABLE
122
VCONTROLLER
112
VNET CABLE
120
VSWITCH
116
VNET CABLE
120
VMODULE
118
I/O
202
SUBSYSTEM/ DEVICE
200

Fig. 2

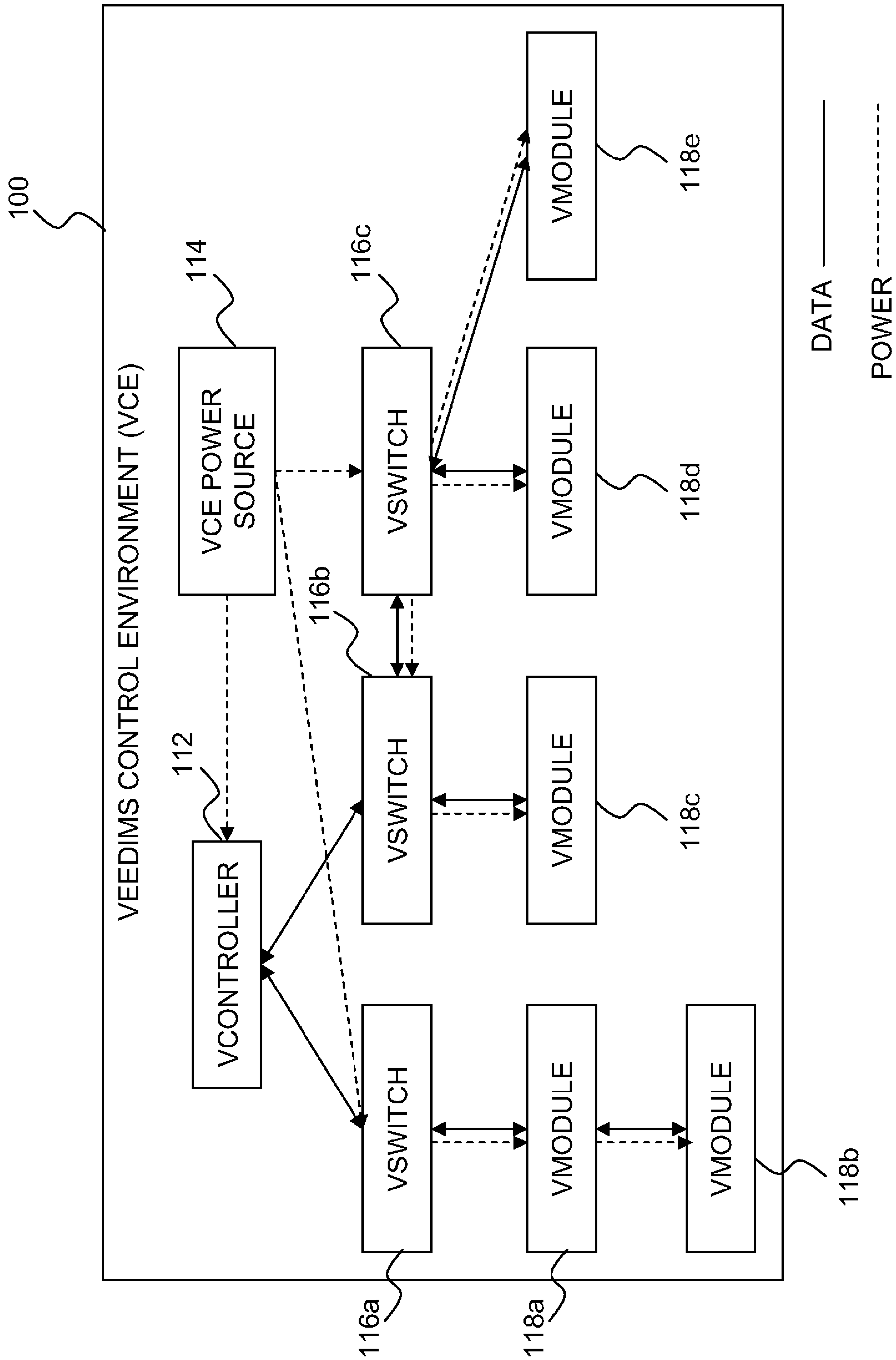

100
VEEDIMS CONTROL ENVIRONMENT (VCE)
VCE POWER SOURCE
114
112
VCONTROLLER
116c
116b
VSWITCH
VSWITCH
VSWITCH
116a
VMODULE
VMODULE
VMODULE
VMODULE
VMODULE
118a
118b
118c
118d
118e
DATA
POWER

Fig. 3

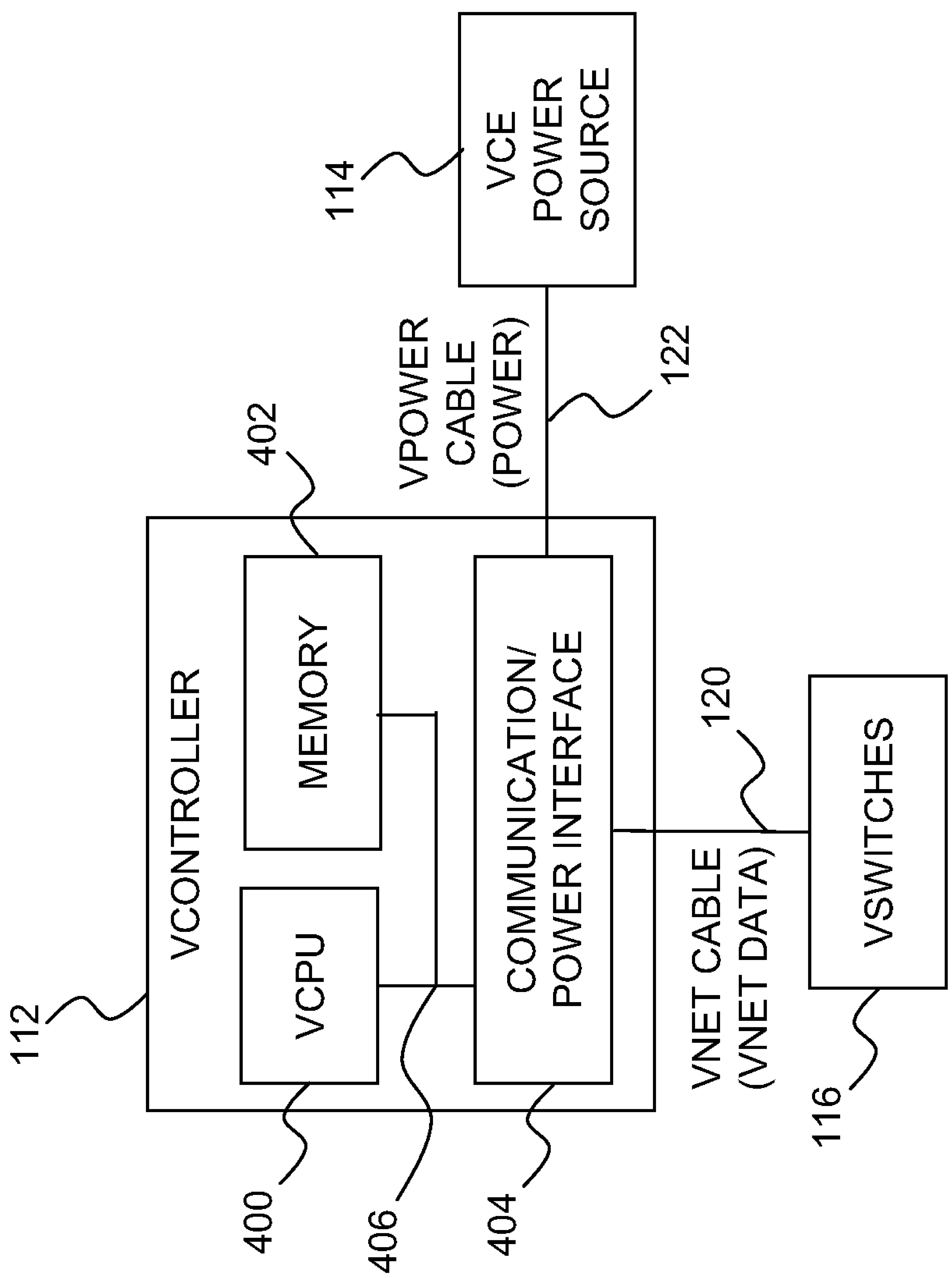

114
VCE
POWER
SOURCE
VPOWER
CABLE
(POWER)
122
402
112
VCONTROLLER
MEMORY
VCPU
COMMUNICATION/
POWER INTERFACE
120
VNET CABLE
(VNET DATA)
VSWITCHES
116
400
406
404

Fig. 4

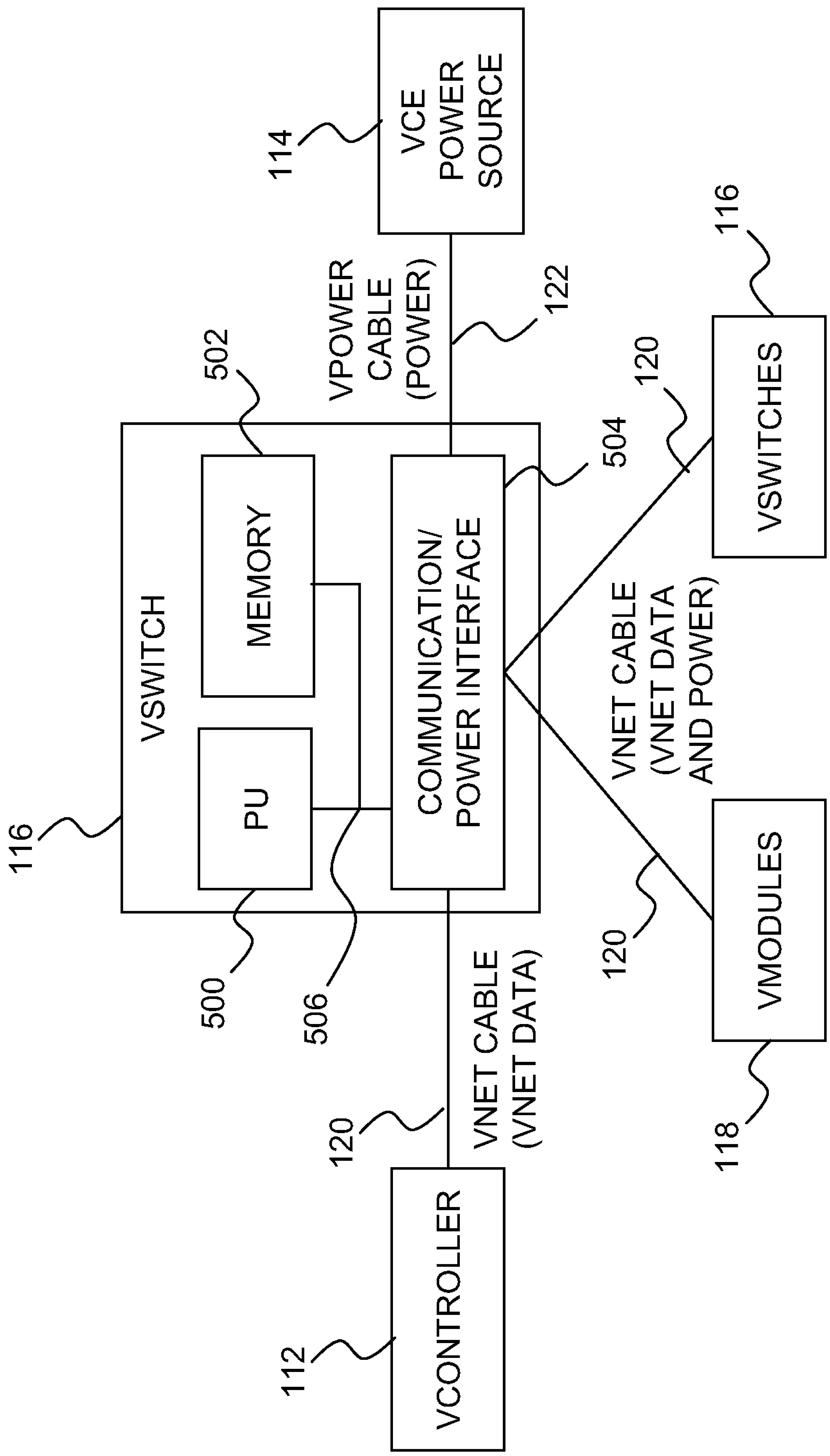

VCE POWER SOURCE
114
VPOWER CABLE (POWER)
122
502
VSWITCH
MEMORY
PU
COMMUNICATION/ POWER INTERFACE
504
116
500
506
VNET CABLE (VNET DATA)
120
VNET CABLE (VNET DATA AND POWER)
120
VSWITCHES
116
VMODULES
118
VCONTROLLER
112

Fig. 5

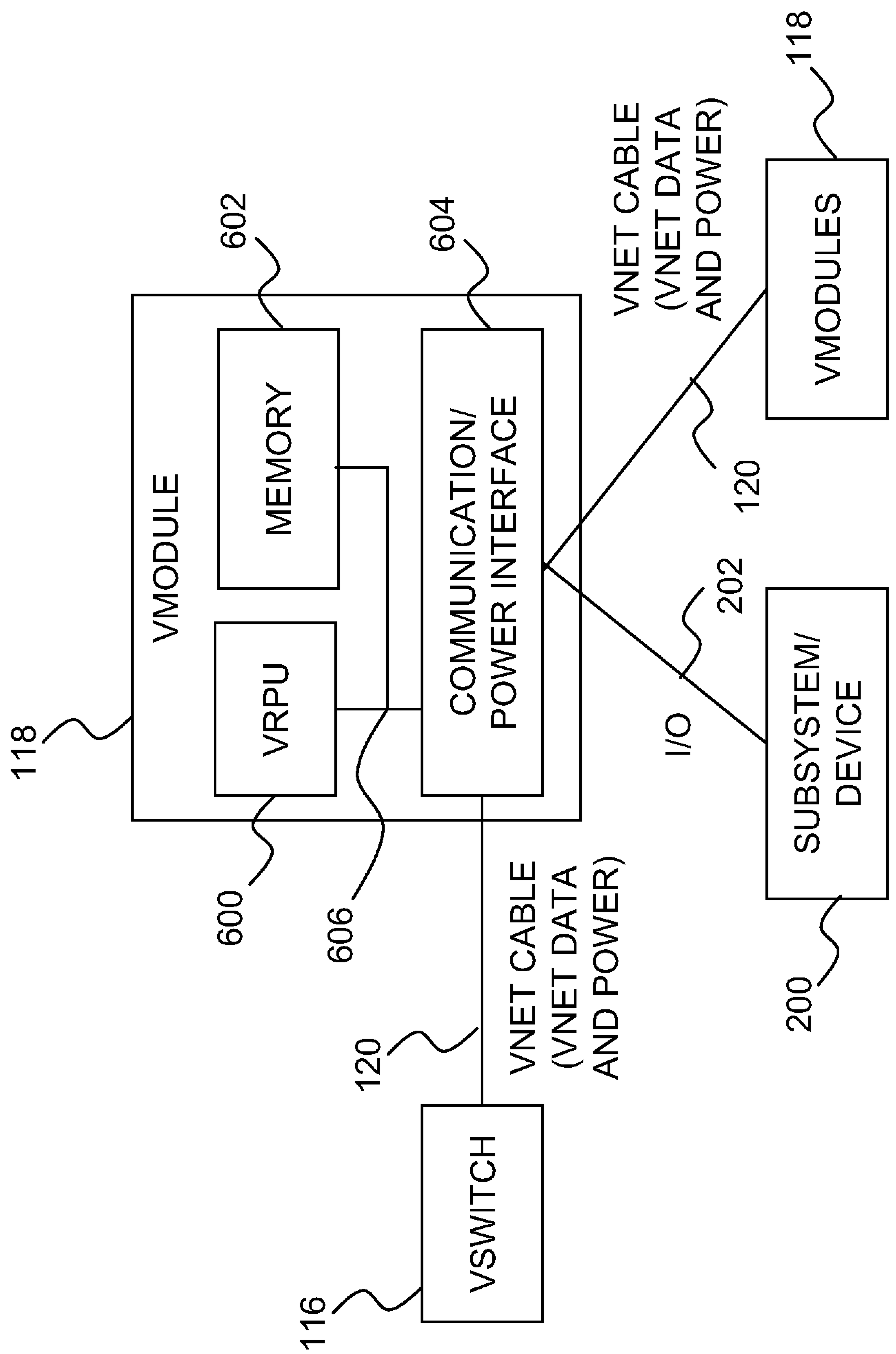
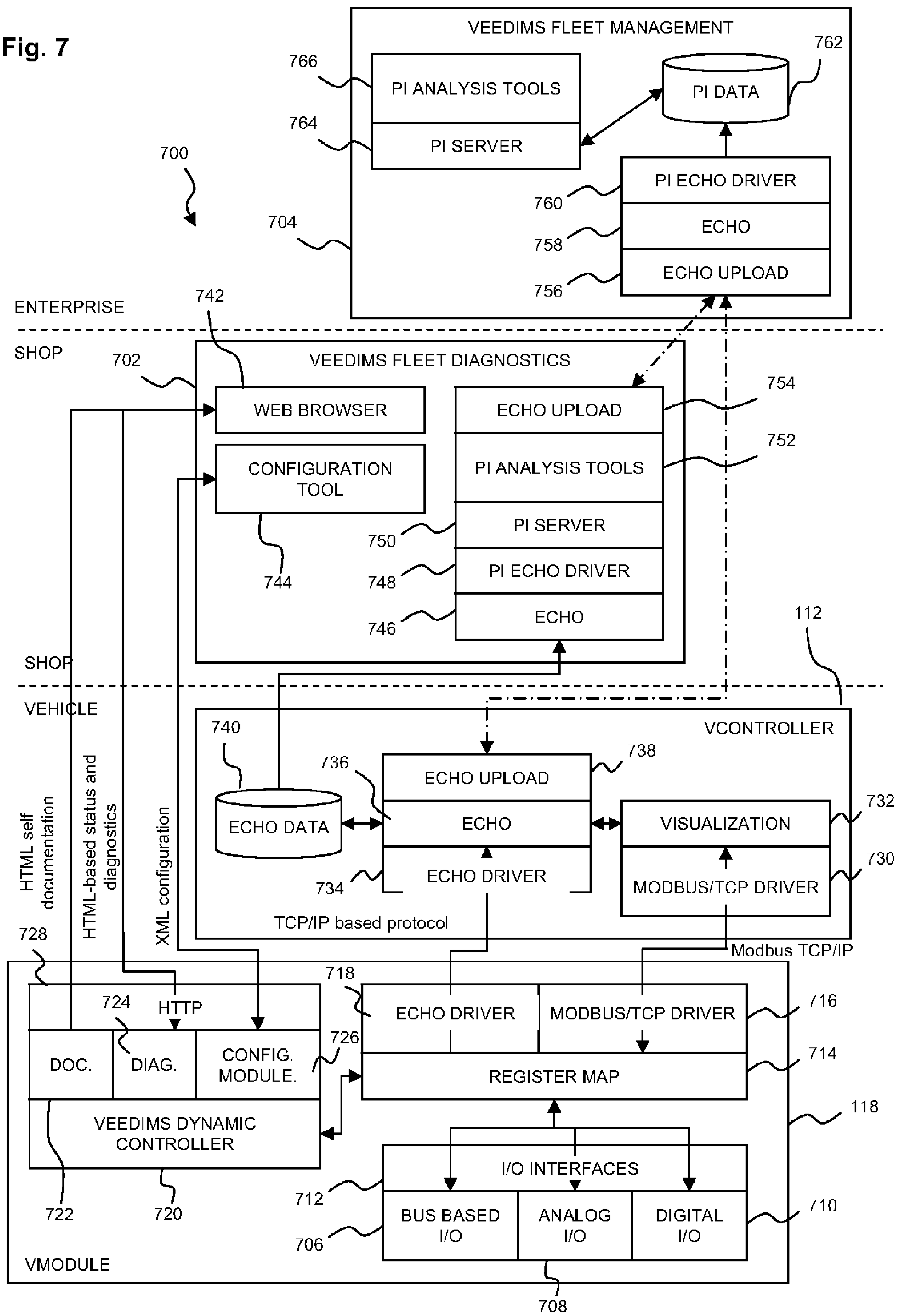

VMODULE
118
VRPU
600
MEMORY
602
COMMUNICATION/
POWER INTERFACE
604
606
VNET CABLE
(VNET DATA
AND POWER)
120
VMODULES
118
I/O
202
SUBSYSTEM/
DEVICE
200
VNET CABLE
(VNET DATA
AND POWER)
120
VSWITCH
116

Fig. 6

Fig. 7


VEEDIMS FLEET MANAGEMENT
PI ANALYSIS TOOLS
PI SERVER
PI DATA
PI ECHO DRIVER
ECHO
ECHO UPLOAD
766
764
762
760
758
756
700
704
742
ENTERPRISE
SHOP
702
VEEDIMS FLEET DIAGNOSTICS
WEB BROWSER
CONFIGURATION TOOL
ECHO UPLOAD
PI ANALYSIS TOOLS
PI SERVER
PI ECHO DRIVER
ECHO
754
752
750
748
746
744
112
SHOP
VEHICLE
VCONTROLLER
740
736
738
ECHO UPLOAD
ECHO
ECHO DATA
ECHO DRIVER
VISUALIZATION
MODBUS/TCP DRIVER
732
730
734
TCP/IP based protocol
Modbus TCP/IP
HTML self documentation
HTML-based status and diagnostics
XML configuration
728
724
HTTP
DOC.
DIAG.
CONFIG. MODULE.
VEEDIMS DYNAMIC CONTROLLER
726
718
ECHO DRIVER
MODBUS/TCP DRIVER
REGISTER MAP
716
714
118
I/O INTERFACES
BUS BASED I/O
ANALOG I/O
DIGITAL I/O
712
706
710
708
722
720
VMODULE

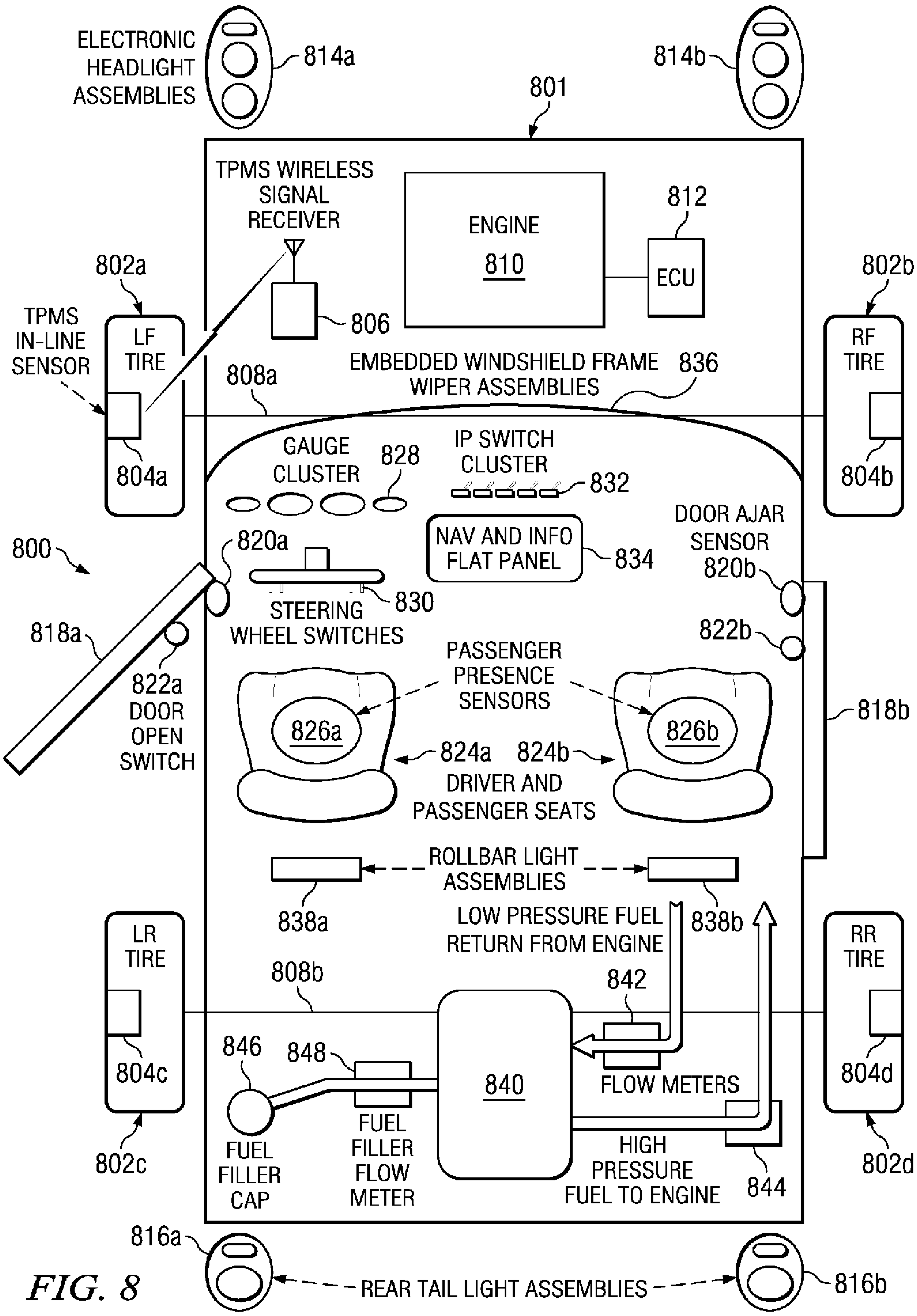

ELECTRONIC HEADLIGHT ASSEMBLIES
814a
814b
801
TPMS WIRELESS SIGNAL RECEIVER
ENGINE
810
812
ECU
802a
802b
TPMS IN-LINE SENSOR
LF TIRE
806
RF TIRE
808a
EMBEDDED WINDSHIELD FRAME WIPER ASSEMBLIES
836
804a
804b
GAUGE CLUSTER
828
IP SWITCH CLUSTER
832
DOOR AJAR SENSOR
820b
800
820a
NAV AND INFO FLAT PANEL
834
830
STEERING WHEEL SWITCHES
818a
822a
DOOR OPEN SWITCH
822b
PASSENGER PRESENCE SENSORS
826a
826b
818b
824a
824b
DRIVER AND PASSENGER SEATS
ROLLBAR LIGHT ASSEMBLIES
838a
838b
LOW PRESSURE FUEL RETURN FROM ENGINE
LR TIRE
RR TIRE
808b
842
846
848
840
FLOW METERS
804c
804d
FUEL FILLER CAP
FUEL FILLER FLOW METER
HIGH PRESSURE FUEL TO ENGINE
844
802c
802d
816a
REAR TAIL LIGHT ASSEMBLIES
816b

FIG. 8

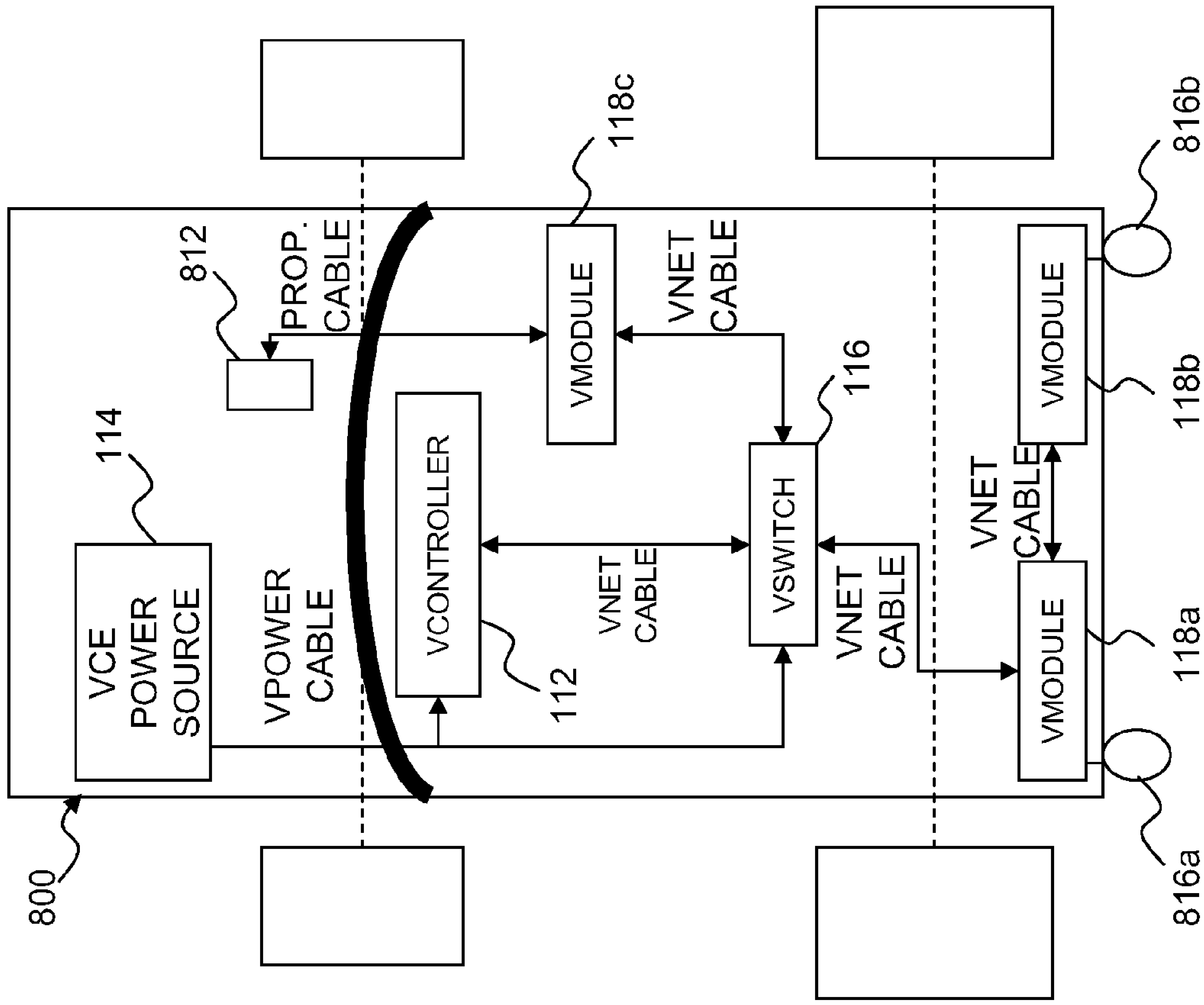

800
VCE
POWER
SOURCE
114
VPOWER
CABLE
812
PROP.
CABLE
VCONTROLLER
112
VNET
CABLE
VMODULE
118c
VNET
CABLE
VSWITCH
116
VNET
CABLE
VMODULE
118a
VNET
CABLE
VMODULE
118b
816a
816b

Fig. 9

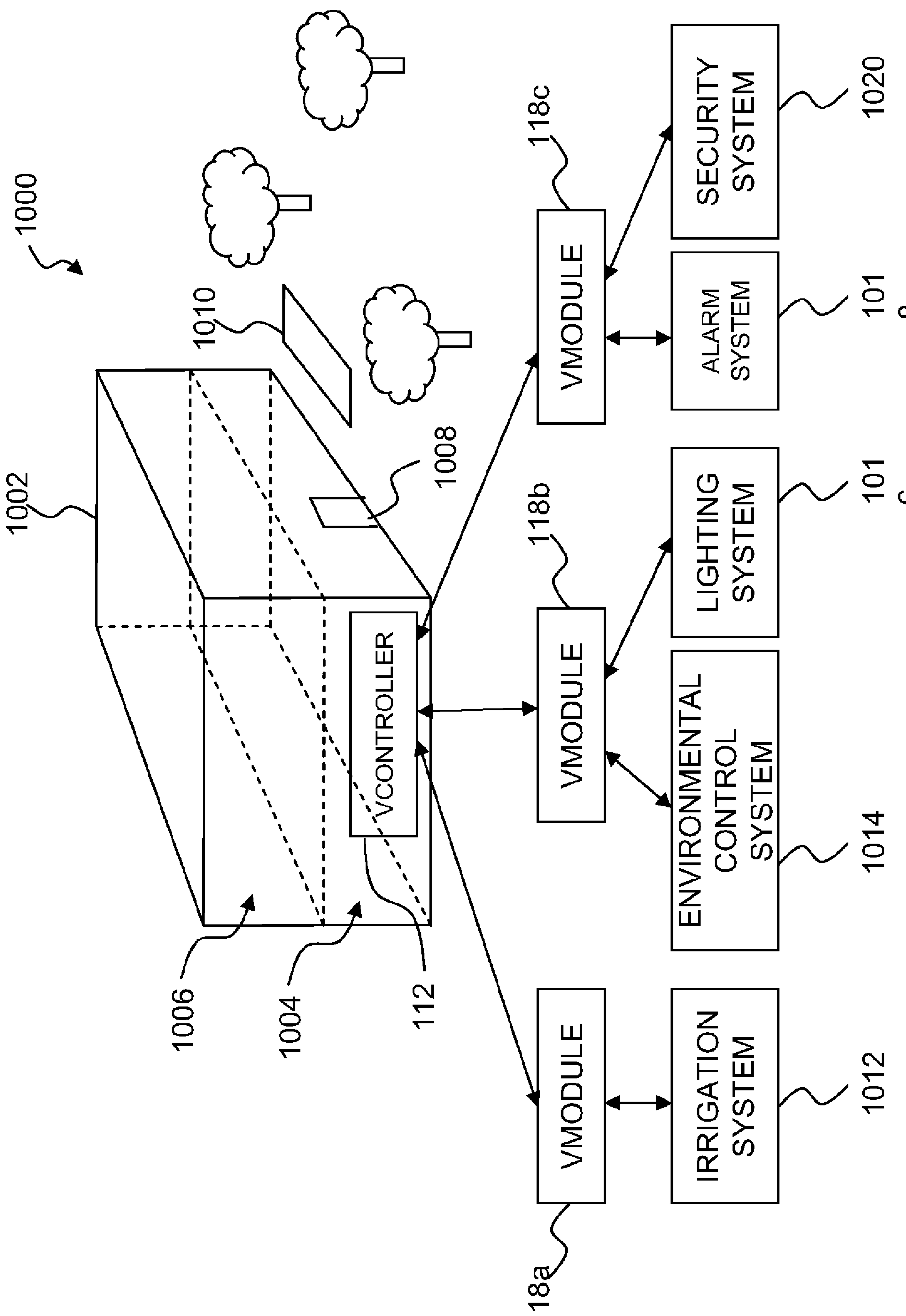

1000
1002
1008
1010
VCONTROLLER
112
1004
1006
VMODULE
118a
VMODULE
118b
VMODULE
118c
IRRIGATION SYSTEM
1012
ENVIRONMENTAL CONTROL SYSTEM
1014
LIGHTING SYSTEM
101 6
ALARM SYSTEM
101 8
SECURITY SYSTEM
1020

Fig. 10

SYSTEM FOR INTEGRATING A PLURALITY OF MODULES USING A POWER/DATA BACKBONE NETWORK

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a Divisional of U.S. application Ser. No. 12/134,424, filed Jun. 6, 2008, published on Jan. 15, 2009, as U.S. Publication No. 2009-0016216. Application Ser. No. 12/134,424 claims the benefit of U.S. Application Ser. No. 60/933,358, filed Jun. 6, 2007.

Patent Application Publication No. 2009-0016216 is hereby incorporated by reference.

TECHNICAL FIELD

The following disclosure relates to control systems and, more particularly, to providing and controlling modular functionality over a power/data backbone.

BACKGROUND

It is well known that power and communication components, particularly in vehicles, are frequently formed as islands of automation in which communication and power distribution with other islands is limited or nonexistent. For example, a vehicle's electrical system is typically limited to an inflexible wiring harness and isolated components that are difficult to troubleshoot and repair. Therefore, a need exists for a system that is able to provide and control an integrated power and data network and corresponding modular components.

SUMMARY

In one embodiment, a Virtual Electrical and Electronic Device Interface and Management System (VEEDIMS) support architecture is provided. The VEEDIMS support architecture comprises a vehicle layer and a shop layer separate from the vehicle layer. The vehicle layer has a module and a controller positioned in a vehicle. The module is configured to couple to a device via an input/output (I/O) interface compatible with the device and configured to couple to a controller via a cable adapted to simultaneously carry bi-directional data and uni-directional power to the module. The module has a first processor and a first memory containing a first instruction set executable by the first processor. The first instruction set includes instructions for providing a HyperText Transfer Protocol (HTTP) server. The first memory further contains a documentation set containing a service history of the module and a bill of materials for at least one of the module and the device that is accessible via the HTTP server and both event driven and time series data captured from the device and the module during operation of the vehicle. The controller has a second processor and a second memory containing a second instruction set executable by the second processor. The second instruction set includes instructions for receiving data from the module and storing the data in the second memory. The data includes the event driven and time series data. The shop layer has a browser and an analysis tool. The browser is configured to communicate with the HTTP server to access the documentation set. The analysis tool is configured to receive the event driven and time series data from the controller and analyze a performance of the vehicle compared to predefined optimal vehicle parameters using the event driven and time series data.

In another embodiment, a Virtual Electrical and Electronic Device Interface and Management System (VEEDIMS) support architecture is provided. The VEEDIMS support architecture comprises a vehicle layer and a shop layer separate from the vehicle layer. The vehicle layer has a plurality of modules and a controller positioned in a vehicle. Each of the plurality of modules is configured to couple to at least one device via an input/output (I/O) interface compatible with the device and configured to couple to the controller via a cable adapted to simultaneously carry bi-directional data and uni-directional power to the module. Each module has a first processor and a first memory containing a first instruction set executable by the first processor. The first instruction set includes instructions for capturing and storing both event driven and time series data from the module and the device during operation of the vehicle. The controller has a second processor and a second memory containing a second instruction set executable by the second processor. The second instruction set includes instructions for receiving data from each of the plurality of modules and storing the data in the second memory. The data includes the event driven and time series data. The shop layer has a communications component, a server, and an analysis tool. The communications component is configured to obtain the data from at least one of the plurality of modules and the controller. The server is configured to store the obtained data. The analysis tool is configured to review and analyze the event driven and time series data to correlate the event driven and time series data to a specific fault event and to view a status of vehicle layer systems during the interval of the specific fault event.

BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding, reference is now made to the following description taken in conjunction with the accompanying Drawings in which:

FIG. **1** illustrates software and hardware layers that may be present in one embodiment of a Virtual Electrical and Electronic Device Interface and Management System (VEEDIMS) control environment (VCE);

FIG. **2** illustrates one possible configuration of the hardware layers in an embodiment of the VCE of FIG. **1**;

FIG. **3** illustrates another possible configuration of the hardware layers in an embodiment of the VCE of FIG. **1**;

FIG. **4** is a block diagram illustrating one embodiment of a VEEDIMS controller that may be used in the VCE of FIG. **1**;

FIG. **5** is a block diagram illustrating one embodiment of a VEEDIMS switch that may be used in the VCE of FIG. **1**;

FIG. **6** is a block diagram illustrating one embodiment of a VEEDIMS module that may be used in the VCE of FIG. **1**;

FIG. **7** illustrates one embodiment of a system architecture that may incorporate aspects of the VCE of FIG. **1**;

FIG. **8** illustrates one embodiment of a vehicle in which the VCE of FIG. **1** may be used;

FIG. **9** illustrates one embodiment of the VCE of FIG. **1** positioned within the vehicle of FIG. **8**; and

FIG. **10** illustrates one embodiment of a structure in which the VCE of FIG. **1** may be used.

DETAILED DESCRIPTION

Referring now to the drawings, wherein like reference numbers are used herein to designate like elements throughout, the various views and embodiments of system and method for integrating a plurality of modules using a power/data backbone network are illustrated and described, and other possible embodiments are described. The figures are not necessarily drawn to scale, and in some instances the drawings have been exaggerated and/or simplified for illustrative purposes only. One of ordinary skill in the art will appreciate the many possible applications and variations based on the following examples of possible embodiments.

The following disclosure describes providing and controlling an integrated power and data network and corresponding modular components to all or portions of a vehicle or a structure. The term "vehicle" may include any artificial mechanical or electromechanical system capable of movement (e.g., motorcycles, automobiles, trucks, boats, and aircraft), while the term "structure" may include any artificial system that is not capable of movement. Although both a vehicle and a structure are used in the present disclosure for purposes of example, it is understood that the teachings of the disclosure may be applied to many different environments and variations within a particular environment. Accordingly, the present disclosure may be applied to vehicles and structures in land environments, including manned and remotely controlled land vehicles, as well as above ground and underground structures. The present disclosure may also be applied to vehicles and structures in marine environments, including ships and other manned and remotely controlled vehicles and stationary structures (e.g., oil platforms and submersed research facilities) designed for use on or under water. The present disclosure may also be applied to vehicles and structures in aerospace environments, including manned and remotely controlled aircraft, spacecraft, and satellites.

Referring to FIG. **1**, in one embodiment, a Virtual Electrical and Electronic Device Interface and Management System (VEEDIMS or simply denoted herein by a "V" prefix) control environment (VCE) **100** is illustrated. The VCE **100** may include software and hardware components arranged into software layers **102** and hardware layers **104** to provide distributed and local level intelligence. Software layers **102** may include a VEEDIMS controller (VController) layer **106**, a VEEDIMS network (VNet) transport layer **108**, and a VEEDIMS module (VModule) driver layer **110**. Hardware layers **104** may include one or more VControllers **112**, a VCE power source **114**, VEEDIMS switches (VSwitches) **116**, and VModules **118**, with connections between the various hardware components provided by VNet cables **120** and/or VEEDIMS power (VPower) cables **122**.

The software layers **102** provide control instructions for the hardware layers **104** and enable the hardware layers to operate, gather data, monitor and report events, and perform other functions needed to provide a VEEDIMS operating environment (VOE). The actual physical location of functionality provided by the software layers **102** may vary depending on the configuration of the VCE **100**. For example, certain software functions may be located in the VController **112** in some configurations, but may be located in the VModule **118** in other configurations.

The VController layer **106** includes a VEEDIMS controller kernel that, among other functions, executes VEEDIMS controller drivers (not shown). The VEEDIMS controller drivers are software modules that are configured to interact with VModules **118** which, as will be described below, directly operate, manage, and monitor electrical and electronic systems operating within the VCE **100**. The VEEDIMS controller drivers are high level drivers that may be relatively generic, with more specific drivers (e.g., in the VModule driver layer **110**) provided in lower software layers that interpret communications between the generic high level drivers and physical component interfaces.

The VNet transport layer **108** may be based on an open protocol, such as an optimized version of the Ethernet protocol, and carries broadcast and/or addressable VNet traffic to support the high speed real-time operational capabilities of the VCE **100**. The VNet traffic is packet-based, and the term "packet" as used in the present disclosure may include any type of encapsulated data, including datagrams, frames, packets, and the like, and the encapsulated information may include voice, video, data, and/or other information. Some or all of the VNet traffic may be encrypted.

The VNet transport layer **108**, in conjunction with a VNet backbone (described below), enables network communications to be integrated down to the discrete input/output (I/O) level using a high bandwidth network. This is in contrast to traditional vehicle networking technology that generally applies networking to accomplish very specific purposes with respect to a given subsystem in the vehicle. In addition to Ethernet, other protocols that may be used by the VNet transport layer **108** include the Transmission Control Protocol/Internet Protocol (TCP/IP), User Datagram Protocol (UDP), HyperText Transfer Protocol (HTTP), Modbus (a serial communication protocol published by Modicon), Bluetooth, Firewire, Controller Area Network (CAN), and Flexray. For example, VEEDIMS may use Modbus TCP as the de-facto Ethernet communication standard and Modbus as the de-facto serial communication standard, with other application specific lower level protocols accessible using Modbus TCP as the gateway.

The VModule driver layer **110** is configured to interact with internal hardware of the VModules **118** and equipment that is physically connected to the VModule internal hardware, as will be described later in greater detail. These may be device specific drivers that are written so that a particular subsystem (e.g., a VModule **118** and a device/component) or device can function within the VCE **100**.

The hardware layers **104** provide a hardware platform on which the software layers **102** may be executed and also provide communication and power links between various subsystems and components. The VControllers **112** run the VEEDIMS controller kernel, which is part of the VController layer **106** and is responsible for managing the VOE. The VControllers **112** are generally responsible for mission critical tasks and may have functionally overlapping responsibilities to minimize problems that may be caused when a VController fails.

One or more VCE power sources **114** may provide electrical energy to all components within the VCE **100**, either directly or indirectly. The VCE power source **114** may be coupled to an electrical grid formed by VNet cables **120** and VPower cables **122**, which are described below. The electrical grid may be a high quality (e.g., aerospace level) grid that uses supervised magnetic hydraulic circuit breakers and cycle by cycle or fold back current limiting electronics to protect components and wiring and to speed diagnostics and fault recovery. Supervision gives the operator of a vehicle an immediate indication of the reason for an electrical system failure and may include steps to be taken to resolve the problem. Current fold back may be used to limit an electrical fault to a subsystem, thereby containing the fault and providing the vehicle with the maximum possible functionality despite the occurrence of the fault.

The VSwitch **116** includes a physical enclosure that contains electronics and connectors needed to enable the VSwitch to act as a conduit for VNet traffic between the VController **112** and VModules **118**. The VSwitch also distributes power (i.e., VPower current) received from the VCE power source **114** to the VModules.

The VModule **118** is a discrete electrical/electronics interface module designed to enable any electrical/electronic device to have digital data and power connectivity to the VCE **100** via a VNet backbone (e.g., a network or a multi-drop communication bus) formed by the VSwitches **116** and VNet cables **120**. In some embodiments, the VModules **118** may include at least limited control functionality.

Interconnections in the VCE **100** are provided by VNet cables **120** and VPower cables **122**. A VNet cable **120** is a physical VNet distribution cabling medium that is capable of providing a digital signal pathway and direct current (DC) voltage interconnections between the VControllers **112**, VSwitches **116**, and VModules **118**. A VPower cable **122** is a physical power distribution cabling medium dedicated to delivering high amperage DC voltage from the VCE power source **114** to the VControllers **112** and VSwitches **116**.

The functionality provided by VNet cables **120** and VPower cables **122** may vary depending on the particular VCE **100**. For example, some VCE implementations may only need to support twelve volt DC power applications, while other implementations may require higher voltages (e.g., twenty-four volts DC, forty-eight volts DC, or 110/220 VAC at 50/60 Hz). In VCE implementations having higher power requirements, dedicated versions of VSwitches **116**, VModules **118**, VNet cables **120**, and VPower cables **122** may be provided. The dedicated versions may be identified by the use of color coded cabling and differently configured and keyed connectors to eliminate the possibility of connecting VSwitches **116** and VModules **118** that are not power compatible.

One embodiment of a VNet cable **120** is formed as an integrated single cable connector assembly that combines power distribution and data networking capabilities. The assembly may include a water-resistant connector that meets a particular ingress protection standard (e.g., qualifies as an IP-67 or similar level protection seal) that provides a rugged interface to a VModule **118** or a sub-system within the VCE **100**. The connector may have a particular power distribution level as described above (e.g., twelve, twenty-four, or forty-eight volts DC or 110/220 VAC 50/60) and may include a neutral contact capable of carrying the required current and a network connector designed for use with multiple high performance protocols. The VNet cable connector may support various levels of Ethernet (e.g., 10baseT, 100baseT, and 1000baseT). Other embodiments may support protocols such as the Universal Serial Bus (USB) protocol, Firewire, CAN, and Flexray in addition to or as alternatives of Ethernet. The VNet cable assembly's connector shell may be manufactured to aerospace standards from a corrosion resistant material with a temperature rating suitable for harsh application environments. A matching jacketed cable assembly may be used that has shielding sufficient to maintain crosstalk or other noise at a level that will not interfere with VNet data traffic.

The VNet cable **120** integrates neutral wiring into a single cable concept to prevent ground loops, reduce noise, and improve reliability. Traditionally, cars, boats, airplanes, and similar environments have used the vehicle's metal chassis as a return path for the DC operating voltage. This is done mainly as a cost saving measure, but can lead to downstream failures. For example, the electrical connections to ground can be at different galvanic potentials depending on the finish and composition of the materials used, and this can accelerate corrosion in an already hostile operational environment. The electrical resistance of circuits can vary over time, leading to varying voltages running through the same common ground, which often induces electrical noise between circuit paths. Accordingly, by using the VNet cable **120**, VEEDIMS minimizes or eliminates these problems due to the VNet cable's configuration as a protected ground wire with gas tight, high reliability connections designed to isolate the electrical circuit return path and minimize or eliminate induced electrical cross talk.

It is understood that many different types of communication media may be used in addition to or as an alternative for the VNet cable **120**, including copper and optic fiber. If optic fiber is used, the VModule **118** or another component of the VCE **100** may perform fiber-to-copper and copper-to-fiber conversions.

With additional reference to FIG. **2**, in another embodiment, one possible configuration of the hardware layers **104** of FIG. **1** is illustrated. In the present example, the VController **112** is coupled to the VCE power source **114** via a VPower cable **122** and to a VSwitch **116** via a VNet cable **120**. The VCE power source **114** is also coupled to the VSwitch **116**, as the VNet cable **120** may not be carrying power and/or may not be capable of providing the amount of power needed to power the VSwitch and components that depend on the VSwitch for power, such as the VModule **118**. The VModule **118** is connected only to the VSwitch **116**, although it may be connected to other VModules as described below. Although not shown, the VController **112** may be directly connected to the VModule **118** in some embodiments (i.e., without an intervening VSwitch **116**). One or both of the VController **112** and VSwitch **116** may communicate with the VCE power source **114** to determine power availability, to pass power consumption needs back to the VCE power source, and to control power levels.

In addition to being coupled to the VSwitch **116**, the VModule **118** may be coupled to a subsystem/device **200** via an input/output (I/O) interface **202**, which may be a VNet cable **120** or another bus-based, analog, and/or digital I/O interface. Although shown as outside of the VCE **100** in the present example, the subsystem/device **200** may be part of the VCE. The VModule **118** may be integrated with the subsystem/device **200** to form a single subsystem or may be separate as shown.

The VCE **100** may support "plug and run" functionality by automatically integrating the VModule **118** or subsystem/device **200** with the VCE after the VModule or subsystem/device is plugged into the VNet backbone. The integration status of the VModule **118** or subsystem/device **200** with the VCE **100** may be indicated by a light emitting diode (LED) or another indicator. For example, when the subsystem **200** is coupled to the VNet backbone, an LED color of the subsystem may indicate the subsystem's integration status. A red LED may indicate that the subsystem **200** is not integrated with the VCE **100** (e.g., due to a lack of available power) and a green LED may indicate that the subsystem is integrated and operational. If not integrated when first plugged in, the LED color may change from red to green if, for example, power becomes available for the subsystem **200**.

The VCE **100** may support self-publishing. In self-publishing, when a new component such as the VModule **118** or a VEEDIMS enabled subsystem or device (e.g., one that has at least basic VModule functionality integrated therein) is connected to the VNet backbone, the new component publishes its "personality" (e.g., power needs, capabilities, and other information). Alternatively, the VController **112** or another component may query the new component to determine its personality. If the new component is a member of a class (as described later), the VCE **100** may already have certain information (e.g., maximum power consumption) about the new component. Accordingly, rather than adding the new component as a part to the VCE **100** in the traditional sense, which often requires entering information about the new component into the VCE, the VCE enables a new component to simply be plugged into the VNet backbone and then identifies relevant information about the new component.

The VCE **100** may support automatic updating. Automatic updating, when a new component such as a VModule **118** or a VEEDIMS enabled subsystem or device (e.g., one that has at least basic VModule functionality integrated therein) is connected to the VNet backbone, the new component may send information to update the higher control levels of the VOE regarding the new component. This avoids human error in entering information regarding the new component.

The VCE **100** may support efficient power use through power splitting. In power splitting, when a new component such as a VModule **118** or a VEEDIMS enabled subsystem or device (e.g., one that has at least basic VModule functionality integrated therein) is connected to the VNet backbone, the VController **112** or another component such as the VSwitch **116** may make a decision as to whether sufficient power exists to operate the new component. This decision may be based on the new component's operating specifications, which may be published by the new component when it is connected or may be obtained by querying the new component. If enough power is available, the amount of power available is decremented and the new component is accepted into the VCE **100** as active. If there is not enough power available, either because the new component's power requirements exceed the available power or some power is being reserved and is not available for use by the new component, the new component is denied access to the VCE **100** or is placed in an inactive status until enough power is available.

If the new component is not VEEDIMS enabled, the VModule **118** into which it is plugged may run tests to determine the new component's power usage or may simply allocate a certain level of power, assuming that the power is available. For example, if a non-VEEDIMS enabled fan is plugged into the VModule **118**, the fan is not capable of publishing information about its personality and cannot be queried to find out such information. Accordingly, the VModule **118** may monitor the fan's operation to identify power and current requirements, temperature, and similar information to build a profile for the fan and to prevent short circuits and other problems. The VModule **118** may then update the VOE using the profile information, thereby serving as a VEEDIMS proxy to provide the non-VEEDIMS enabled fan with at least basic VEEDIMS functionality.

Power splitting may also make the VCE **100** more environmentally friendly as power consumption can be monitored and controlled at different levels of the VCE to ensure that it is being used efficiently. This control may be used to identify high power requirement components for replacement and to generally regulate power consumption within the VCE **100**.

The VCE **100** may support software and hardware redundancy. For example, hardware redundancy may be provided by using multiple hardware components (e.g., VControllers **112**) for mission critical operations and by providing dual ports and other safeties for the VControllers **112**, VSwitches **116**, and VModules **118**. Some or all of the VControllers **112**, VSwitches **116**, and VModules **118** may also use heartbeat or other notification methods to enable the VCE **100** to detect software, hardware, and link failure and to adjust accordingly.

With additional reference to FIG. **3**, in yet another embodiment, one possible configuration of the VCE **100** of FIG. **1** illustrates the ability to couple multiple VSwitches **116** and VModules **118** to one another (i.e., daisy chain). The ability to daisy chain VSwitches **116** eliminates the need to run separate VNet cables **120** and VPower cables **122** from each VSwitch back to the VController **112** and the VCE power source **114**, respectively, in the VCE **100**. Similarly, the ability to daisy chain VModules **118** eliminates the need to run separate VNet cables **120** from each VModule back to the VSwitch **116**. This enables the cabling to be run more efficiently, as the VCE **100** may be configured with multiple VSwitches **116** and VModules **118** distributed throughout a vehicle or other environment.

Daisy chaining may include power, data, or both power and data. One or more of the VSwitches **116** and VModules **118** may include an Ethernet switch configured to pass data through to other VSwitches and VModules to enable VNet traffic daisy chaining. Furthermore, power may be sent in one direction of a daisy chain and data may be sent in the other direction. Accordingly, a high level of flexibility is available for any given configuration of the VCE **100** while providing a distributed and de-coupled (i.e., modular) system.

In the present example, VController **112** is coupled to VCE power source **114** for power (dotted line) and to VSwitches **116***a* and **116***b* for VNet data communications (solid lines). VSwitch **116***a* supplies VNet data and power to VModule **118***a*, which in turn supplies VNet data and power to daisy chained VModule **118***b*. VSwitch **116***b* is coupled to VSwitch **116***c* and VModule **118***c* and supplies VNet data to VSwitch **116***c* and both VNet data and power to VModule **118***c*. Note that VSwitch **116***b* is not coupled directly to VCE power source **114**. VSwitch **116***c* is coupled to VModules **118***d* and **118***e* as well as VSwitch **116***b*. VSwitch **116***c* supplies power to VSwitch **116***b* and both VNet data and power to VModules **118***d* and **118***e*. Although not shown, the VController **112** and/or VSwitches **116** may communicate with the VCE power source **114** to determine power availability, to pass power consumption needs back to the VCE power source, and to control power levels.

Additional VSwitches **116** (not shown) may be coupled to VController **112** and/or daisy chained from VSwitches **116***a*-**116***c*, and additional VModules **118** (not shown) may be coupled to one of the VSwitches **116***a*-**116***c* or daisy chained from VModules **118***a*-**118***e*. Furthermore, multiple VSwitches **116** may be coupled to a single VSwitch and multiple VModules **118** may be coupled to a single VModule. Constraints to the number of VSwitches **116** and VModules **118** that can be connected may include the number of available ports and the amount of power needed by the chained components versus the amount of power available to the chain. The number of connections required for relatively long chains may increase the difficulty of replacing cables and components.

Although not shown, it is understood that many different network topographies may be used. For example, both ring network configurations and star network configurations may be used in the VCE **100**.

Referring to FIG. **4**, one embodiment of the VController **112** of FIG. **1** is illustrated. The VController **112** includes a VEEDIMS central processing unit (VCPU) **400**, a memory **402**, a communication/power interface **404**, and one or more internal communication links **406**. It is understood that the configuration and types of components of the VController **112** may vary depending on the particular VCE **100** in which the VController is to be used. For example, in a vehicular environment, the VController **112** may be designed as a relatively compact integrated circuit board with the minimum number of ports that are needed to provide the desired functionality. In contrast, an environment such as a structure (e.g., a home or office building) may use a less compact VController **112** as space is generally less important. Furthermore, the VController **112** may be relatively generic for use in many different VCEs, or may be customized for use in a particular VCE **100** having highly specific requirements (e.g., an aerospace environment).

The VCPU **400** may actually represent a multi-processor or a distributed processing system; the memory **402** may include different levels of cache memory, main memory, hard disks, and remote storage locations; and the communication/power interface **404** may represent multiple interfaces dedicated to receiving, splitting/combining data and power, and transmitting. For example, the communication/power interface **404** may have a first interface (not shown) that receives power from the VCE power source **114** via a VPower cable **122** and a second interface (not shown) that communicates with one or more VSwitches **116** via a VNet cable **120**. In some embodiments, the VController **112** may also send power to the VSwitches **116** via the VNet cable **120**. The data transmission capabilities of the communication/power interface **404** may provide both wireline (e.g., the VNet cable **120**) and wireless functionality.

Instructions for the VController layer **106** (e.g., the VEEDIMS controller kernel and VEEDIMS controller drivers) and VNet transport layer **108** may be stored in the memory **402** and executed by the VCPU **400**. The VController layer **106** functionality may be handled entirely by the VController **112**, or some or all of the VController layer functionality may be pushed down to the VSwitch **116** level or lower. As will be discussed later, additional functionality may be provided by the VController **112** to allow users to interact with the VController in order to control parameters of the VCE **100** and to obtain data regarding the VCE. If multiple VControllers **112** are present in the VCE **100**, they may include software to provide load balancing functionality and to ensure redundancy if one of the VControllers fails.

Referring to FIG. **5**, one embodiment of the VSwitch **116** of FIG. **1** is illustrated. The VSwitch **116** includes a processing unit (PU) **500**, a memory **502**, a communication/power interface **504**, and one or more internal communication links **506**. It is understood that the configuration and types of components of the VSwitch **116** may vary depending on the particular VCE **100** in which the VSwitch is to be used. For example, in a vehicular environment, the VSwitch **116** may be designed as a relatively compact integrated circuit board with the minimum number of ports that are needed to provide the desired functionality. In contrast, an environment such as a structure (e.g., a home or office building) may use a less compact VSwitch **116** as space is generally less important. Furthermore, the VSwitch **116** may be relatively generic for use in many different VCEs, or may be customized for use in a particular VCE **100** having highly specific requirements (e.g., an aerospace environment).

The PU **500** may actually represent a multi-processor or a distributed processing system and the memory **502** may include different levels of cache memory, main memory, hard disks, and remote storage locations. In the present example, the PU **500** and memory **502** may be formed on a circuit board with an embedded system such as is made by Netburner, Inc., of San Diego, Calif. The circuit board may include multiple ports for power, communications, and other connections.

The communication/power interface **504** may represent multiple interfaces dedicated to receiving VNet data traffic and power, splitting/combining VNet data traffic and power, and transmitting VNet data traffic and power. For example, the communication/power interface **504** may have a first interface (not shown) that receives power from the VCE power source **114** via a VPower cable **122** and passes the power to the PU **500** and memory **502**, and a second interface (not shown) that communicates with the VController **112**, VSwitches **116**, and VModules **118** via VNet cables **120**.

The second interface may be configured to recognize that the VNet cable **120** linking the VSwitch **116** to the VController **112** does not have a power component, or the VNet cable linking the two may be inserted into a designated slot in the VSwitch that does not support power. The communication/power interface **504** may include a connection between the first and second interfaces to pass power received via the VPower cable **122** to the VNet cables **120** that are coupled to other VSwitches **116** and VModules **118**. If the VNet cables **120** have two separate channels for data and power, the first and second interfaces may be independently coupled to the appropriate channel. If the data and power are carried in a single signal (e.g., at separate frequencies), the first and second interfaces may merge the VNet data traffic and power signals to create a single outgoing signal.

The first and second interfaces of the communication/power interface **504** may also be configured to allow some or all of the VNet data traffic and power to pass through the VSwitch **116**. For example, if another VSwitch **116** is coupled to an input/output port of the communication/power interface **504** via a VNet cable **120**, the communication/power interface may pass some of the received power through to the other VSwitch as well as some or all of the received VNet data traffic. The communication/power interface **504** may also include filters or other control circuitry that enable the VSwitch **116** to control the delivery of power via the VNet cable **120**. The data transmission capabilities of the communication/power interface **504** may provide both wireline (e.g., the VNet cable **120**) and wireless functionality.

Instructions for the VNet transport layer **108** and for interacting with the VController layer **106** may be stored in the memory **502** and executed by the PU **500** to establish the VSwitch **116** as a Multiple Application Execution Interface (MAXI) in the VCE **100**. In some embodiments, the VSwitch **116** may contain instructions for at least a portion of the VController layer **106**. In other embodiments, the VSwitch **116** may provide only basic VNet data traffic switching (e.g., in a VCE **100** having individually addressable VModules **118**) and may simply pass any remaining power through to connected VSwitches and VModules after its own power consumption needs are met.

Referring to FIG. **6**, one embodiment of the VModule **118** of FIG. **1** is illustrated. As described previously, the VModule **118** is a discrete electrical/electronics interface module designed to enable any electrical/electronic device to have data and power connectivity to the VCE **100** via the VNet backbone formed by the VSwitches **116** and VNet cables **120**. Generally, the VModule **118** is designed to provide a hardware (and, in some applications, a software) abstraction layer to the VOE so that generic software control drivers operating at the VController layer **106** residing in the VController **112** can control such low level devices as, for example, instrument panel gauges that might be found in motorized vehicles.

The VModule **118** includes a VEEDIMS remote processing unit (VRPU) **600**, a memory **602**, a communication/power interface **604**, and one or more internal communication links **606**. It is understood that the configuration and types of components of the VModule **118** may vary depending on the particular VCE **100** in which the VModule is to be used. For example, in a vehicular environment, the VModule **118** may be designed as a relatively compact integrated circuit board with the minimum number of ports that are needed to provide the desired functionality. In contrast, an environment such as a structure (e.g., a home or office building) may use a less compact VModule **118** as space is generally less important.

Furthermore, the VModule **118** may be relatively generic for use in many different VCEs, or may be customized for use in a particular VCE **100** having highly specific requirements (e.g., an aerospace environment).

The VRPU **600** may actually represent a multi-processor or a distributed processing system and the memory **602** may include different levels of cache memory, main memory, hard disks, and remote storage locations. In the present example, the VRPU **600** and memory **602** may be formed on a circuit board with an embedded system such as is made by Netburner, Inc., of San Diego, Calif. The circuit board may include multiple ports for power, communications, and other connections.

The communication/power interface **604** may represent multiple interfaces dedicated to receiving VNet data traffic and power, splitting/combining VNet data traffic and power, and transmitting VNet data traffic and power. For example, the communication/power interface **604** may have a first interface (not shown) that receives power from the VNet cable **120** coupled to the VSwitch **116** and a second interface (not shown) that receives and transmits VNet data via the same VNet cable. If the VNet cable has two separate channels for data and power, the first and second interfaces may be independently coupled to the appropriate channel. If the data and power are combined in a single signal (e.g., at separate frequencies), the first and second interfaces may filter the incoming signal to separate the data and power.

The first and second interfaces of the communication/power interface **604** may be configured to allow some or all of the VNet data traffic and power to pass through the VModule **118**. For example, if another VModule **118** is coupled to an input/output port of the communication/power interface **604** via a VNet cable **120**, the communication/power interface **604** may pass some of the received power through to the other VModule as well as some or all of the received VNet data traffic. The data transmission capabilities of the communication/power interface **604** may provide both wireline (e.g., VNet cable **120**) and wireless functionality.

The first and second interfaces of the communication/power interface **604** may connect the VModule **118** with one or more subsystems/devices **200**. For example, one or both of the first and second interfaces may form the I/O interface **202** of FIG. **2**, or the communication/power interface **604** may include one or more other bus-based, analog, and/or digital I/O interfaces for communication and power distribution to the subsystems/devices **200**. The VModule **118** may perform exception reporting for faults in attached subsystems/devices **200** using, for example, I/O scanning via the I/O interface **202**. In some embodiments, the communication/power interface **604** of the VModule **118** may serve as a gateway to provide access for the attached subsystems/devices **200** to external wireless devices (not shown).

Instructions for the VNet transport layer **108**, VModule driver layer **110**, and for interacting with the VController layer **106** may be stored in the memory unit **602** and executed by the VRPU **600** to configure the VModule **118** as a MAXI in the VCE **100**. In some embodiments, the VModule **118** may contain instructions for at least a portion of the VController layer **106**.

The VModule driver layer **110** includes dedicated device interface specific driver software that provides an interface between the VOE and the subsystems/devices **200** coupled to the VModule **118**. For example, in a VCE **100** such as a vehicle, signal data from discrete sensors such as oil temperature, pressure, water temperature, etc., are captured from subsystems/devices **200** via specific drivers of the VModule driver layer **110**, aggregated, and processed by the VModule **118**. The VModule **118** takes the sensor data and sends it as VNet traffic (e.g., as a VEEDIMS compatible data stream) over the VNet backbone to the VController **112**. It is understood that sensor data that is not VEEDIMS compatible may be converted by the VModule **118** prior to sending it to the VController **112**. In a more specific example, a VController layer driver in the VController layer **106** may be developed to drive a tachometer, speedometer, and a series of other gauges in order to inform an operator of the vehicle's current status. To achieve this, discrete sensors connected to the VModule **118** generate digital or analog signal data, which is aggregated and processed by the VModule based on the corresponding VModule driver layer **110**. The VModule **118** transmits the processed signal data to the VController **112** via the VNet backbone for processing by the VCPU **400**. The VController **112** can then present the information to the vehicle's operator.

The VModule **118** enables new subsystems and components to be integrated with the VOE without requiring high level changes. For example, to support new physical electrical/electronic equipment and any corresponding software, a driver may be written for the VModule **118**. The driver, which would be in the VModule driver layer **110**, would be written to conform to the VEEDIMS standard interface protocol used by the VController layer **106**. The standard interface protocol may be available via a VEEDIMS development kit (VDK) or otherwise published for use by developers. This approach is conceptually similar to the idea of a generic disk drive controller driver that is written in a UNIX operating system environment for controlling disk drives. When a new disk drive is developed, regardless of any new operational capabilities at its hardware level, the generic disk drive controller driver is capable of interacting with the new drive because any unique aspects of the new drive are transparent to the generic device driver as long as the new drive's low level driver is designed to be compatible to the higher level generic disk drive controller driver. Accordingly, new subsystems and components may be integrated with the VCE **100** without requiring high level VCE changes as long as their drivers conform to the VEEDIMS standard interface protocol.

The VModule **118** may have a unique identifier that can be used within the VCE **100** to distinguish it from other VModules. The unique identifier may be a media access control (MAC) address, IP address, or any other unique identifying code (e.g., a serial number).

As will be described below in greater detail, the VModule **118** may maintain its own fully encrypted password protected internal website stored in non-volatile memory (e.g., the memory **602**). The information may include product documentation and revision levels, a complete bill of materials (BOM), and repair and manufacturing history. The VModule **118** may broadcast or send this data to peer VModules and higher level component (e.g., VSwitches **116** and VController **112**) in the VCE **100**. The VModule **118** may maintain a cached data snapshot of events prior to a failure in non-volatile memory for fault analysis, and may also store run hours and other parameters of interest. Using such information, replacement of a failed VModule **118** may be accomplished without the need to reconfigure the VCE's software. The VModule **118** may be configured to execute a diagnostic at startup and report its status as needed. Furthermore, VModules **118**, as well as VSwitches **116** and VControllers **112**, may all generate a heartbeat signal, and the VController **112** may monitor the heartbeats to determine the status of various VCE components.

Referring to FIG. **7**, one embodiment of a system architecture **700** is illustrated. The system architecture **700** views the

VCE **100** as having an information top layer that is widely accessible and may be manipulated, a middle control layer that is mission critical, and a device layer. The system architecture **700** focuses on the information top layer and uses the underlying layers mainly for data acquisition and diagnostics. For purposes of example, the system architecture **700** is described with respect to a vehicle layer, a shop (e.g., a vehicle repair garage) layer, and an enterprise layer. The VCE **100** in the present embodiment includes the VController **112** and VModule **118** of FIG. **1** in the vehicle layer, VEEDIMS fleet diagnostics **702** in the shop layer, and VEEDIMS fleet management **704** in the enterprise layer. In the present example, the PI System provided by OSIsoft, Inc., of San Leandro, Calif., is used for data acquisition, compilation, and analysis. However, it is understood that other systems may be used and the present disclosure is not limited to the PI system.

In the present embodiment, the VCE **100** of FIG. **1** is configured to support serial data storage, which enables time and excursion based fault analysis after an event (e.g., a failure) occurs. Traditional automotive diagnostic systems are based on an error code paradigm. In the error code paradigm, a specific fault generates a pre-defined error code stored in a computer, theoretically allowing a service technician to diagnose the root cause of the fault and repair the system. Unfortunately, this pre-defined error code approach cannot capture an unforeseen fault event or a sequence of events, which often results in extended troubleshooting sessions that may never identify the root cause of the original problem. For example, if the error cannot be isolated, large sections of wiring harness or even larger part assemblies may be replaced in an attempt to eliminate the fault generating component. Such a trial and error approach to problem solving is extremely costly to the customer, the dealer, and the manufacturer.

The present disclosure addresses this issue by providing the system architecture **700** to support the high resolution capture of all time series and event driven data and its storage in compact non-volatile digital media. The system also allows the data to be reviewed and analyzed to view the status of various systems during the interval of a specific fault. This capability enables the correlation of system data to a specific fault event noticed by the customer or recorded by the VCE **100**, and also enables pre-event data streams to be analyzed in order to develop a comprehensive picture of what may have led up to the failure. This analysis process enables a service technician to use computerized tools to rapidly and efficiently diagnose the cause of intermittent faults, which are traditionally the most difficult fault event to detect and repair.

The VCE **100** may also provide the ability to store all of the collected data that is generated. By allowing filtering only for compression and exceptions, storage efficiency may be increased without losing resolution. Furthermore, by using transmission technologies (e.g., Bluetooth and other wireline and wireless technologies), the accumulated data can be downloaded for later analysis directed to identifying improvements rather than simply addressing current issues. For example, the data may be analyzed to identify fault conditions that can be used to define predictive means for preventing future component failures.

The data may be organized for fast retrieval and advanced searches, such as searches for logical expressions or excursion outside limits. In some embodiments, the data storage (e.g., a database) may use a batch sub-system that stores pointers to the beginning and end of specific parts of the data streams, thereby allowing for comparisons between similar events using overlay. For example, all engine start events may be organized by the batch sub-system so the start events can be recalled quickly and compared in order to develop a model of an optimal engine start and to predict the need for maintenance as parameters drift (e.g., cranking time on cold start). The efficiency of the database allows for sophisticated analysis, including multivariate statistical analysis. This may enable real-time data analysis that can not only perform fault detection, but can also execute preventive maintenance functions by observing trends that move away from normal operational parameters. In some examples, the VCE **100** may be configured for control based on a golden profile (e.g., an optimal set of performance parameters) and to trigger an alarm when the performance drifts away from the profile.

To achieve this level of analysis, the VModule **118** gathers information regarding attached subsystems/devices **200** (FIG. **2**) using sensors and other feedback mechanisms. The information may be obtained via interfaces such as a bus-based I/O interface **706**, an analog I/O interface **708**, and a digital I/O interface **710**. Each of the I/O interfaces **706**, **708**, and **710** passes information through a generic I/O interface layer **712** that allows the VModule **118** to communicate in a uniform manner with each of the different types of I/O interfaces.

The I/O interface layer **712** stores the information in a register map **714**, which is accessible to a Modbus/TCP driver **716** and an Embedded Component Historian Object (ECHO) driver **718** (e.g., ECHO as supported by the PI System provided by OSIsoft, Inc., of San Leandro, Calif.). The Modbus/TCP driver **716** and ECHO driver **718** interface with corresponding components of the VController **112** as will be described later.

The register map **714** is also accessible to a VEEDIMS dynamic controller **720** that is configured to obtain information from the register map, process the information, and update and maintain documentation **722**. Documentation version control may be a complex problem in vehicles with high degrees of sophistication or having a large manufacturing volume. To solve this problem, VEEDIMS embeds the entire documentation set within the VModule **118** or in another sub-system, making it instantly available to a service technician. In addition, a service log may be stored that can be updated to accurately reflect the service history of the vehicle. In some embodiments, the service log may be linked to a billing system that will automatically update the log.

The dynamic controller **720** may also perform diagnostics and maintain information resulting from the diagnostics using a diagnostics module **724**, and may configure VModule and subsystem/device parameters and maintain configuration information using a configuration module **726**. The dynamic controller **720** may make the documentation **722** and information related to the diagnostics module **724** and configuration module **726** available via a HyperText Transfer Protocol (HTTP) interface **728** using the previously described embedded web server. In the present example, the information is made available to the VEEDIMS fleet diagnostics **702** in the shop layer, but it may be made available to many other users, including an operator of the vehicle corresponding to the VCE **100**.

The VController **112** includes a Modbus/TCP driver **730** that receives information from the register map **714** via the Modbus/TCP driver **716** of the VModule **118**. The Modbus/TCP driver **730** passes the information into a visualization module **732** that may process the information before passing the processed information to an ECHO component **736**. The VController **112** also includes an ECHO driver **734** that receives information from the register map **714** via the ECHO driver **718** of the VModule **118**. The ECHO driver **734** passes the information to the ECHO component **736**. The ECHO component **736** may send some or all of the information to VEEDIMS fleet management **704** in the enterprise layer via an ECHO upload component **738**. The ECHO component **736** may also store all or some of the information in an ECHO data database **740**, which may be responsible for gathering and archiving large amounts of time-stamped data at high speeds (e.g., real time or near real time).

Some or all of the data stored by the VController **112** and VModule **118** may be stored in a "black box" designed to withstand high impact and high temperature situations, such as an accident. The data described above may then be available for analysis even if various subsystems are damaged or destroyed.

VEEDIMS fleet diagnostics **702** in the shop layer includes a web browser **742** that may be used to access and view documentation data **722** and diagnostics data **724** via the HTTP interface **728** provided by the web server of the VModule **118**. Due to the HTTP nature of the data presented by the VModule **118**, access to the data can be accomplished without the need for proprietary equipment and tools. As the data may be encrypted, security may be maintained as only users with the proper authorization credentials can access the data. The VEEDIMS fleet diagnostics **702** may also include a configuration tool **744** that may be used to interact with the configuration module **726** to obtain configuration information and to configure parameters of the VModule **118**, other VModules, and attached subsystems/devices using eXtensible Markup Language (XML) configuration information.

VEEDIMS fleet diagnostics **702** further includes an ECHO component **746** that obtains data from the ECHO data database **740** of the VController **112**. The data may be passed to a PI server **750** via a PI ECHO driver **748** and various PI analysis tools **752** may be used to analyze some or all of the data in the shop layer. The data may be passed to VEEDIMS fleet management **704** in the enterprise layer via an ECHO upload component **754**.

VEEDIMS fleet management **704** in the enterprise layer includes an ECHO upload component **756** that receives data from the ECHO upload components **738** and **754**. The ECHO upload component **756** passes the data to an ECHO component **758**, which stores the data in a PI data database **762** via a PI ECHO driver **760**. PI analysis tools **766** may access the data in the PI data database **762** for analysis via a PI server **764**.

Referring to FIG. **8**, in one embodiment, a vehicle **800** is illustrated as an environment that may be managed using the VCE **100** of FIG. **1**. The vehicle **800** includes a chassis **801** and positioned within or coupled to the chassis are a plurality of subsystems and corresponding components that provide propulsion, steering, braking, and other functionality to the vehicle **800**. It is understood that the subsystems and components described herein are for purposes of example only, and that many other subsystems and components may be used with the vehicle **800**. Furthermore, illustrated subsystems and components may be configured differently from those illustrated and may be positioned in differently within the vehicle **800**.

The vehicle **800** includes tires **802***a*, **802***b*, **802***c*, and **802***d* and corresponding tire pressure monitoring system (TPMS) in-tire sensors **804***a*, **804***b*, **804***c*, and **804***d*, respectively, which send signals to a TPMS wireless signal receiver **806**. The tires **802***a*, **802***b*, **802***c*, and **802***d* are coupled to axles **808***a* and **808***b* that are powered via a transmission system (not shown) coupled to an engine **810**. An Engine Control Unit (ECU) **812** may monitor and manage the performance of the engine **810**. For example, the ECU **812** may control fuel injection in the engine **810** based on monitored parameters.

Headlight assemblies **814***a* and **814***b* and tail light assemblies **816***a* and **816***b* may be coupled to an electrical system that enables manipulation of various lights forming the headlight and tail light assemblies.

Doors **818***a* and **818***b* may be monitored using "door ajar" sensors **820***a* and **820***b*, respectively. "Door open" switches **822***a* and **822***b* may be used to control interior lights, alarms, and other functions when doors **818***a* and **818***b*, respectively, are opened. Driver seat **824***a* and passenger seat **824***b* may include presence sensors **826***a* and **826***b*, respectively, which indicate the presence of a person.

The passenger compartment may also contain a gauge cluster **828** for providing feedback information to the driver (e.g., speed, fuel level, and engine temperature), various actuation means (e.g., switches and buttons) positioned on a steering wheel **830**, an instrument panel switch cluster **832**, and an interactive navigation and information screen **834** (e.g., a flat panel). The interactive screen **834** may be used to provide navigation information, vehicle information (e.g., a current fuel level, estimated remaining mileage before fuel is needed, and various temperatures (e.g., engine and passenger compartment temperatures)), and other information to a user. Windshield wiper assemblies **836** may be controlled via the actuation means on the steering wheel **830**. Rollbar light assemblies **838***a* and **838***b* may be coupled to an electrical system that enables manipulation of various lights on the rollbar light assemblies via, for example, the interactive screen **834**.

A fuel cell **840** may be coupled to a flow meter **842** that measures fluid flow on a low pressure fuel return from the engine **810** and a flow meter **844** that measures fluid flow on a high pressure fuel line to the engine. A fuel cap **846** may cover a fuel fill line that is monitored by a flow meter **848**. Although not shown, a sensor may monitor the fuel cap **846** to ensure that it is in place. The fuel cell **840** and the various flow meters **842**, **844**, and **848** may be monitored.

It is understood that the vehicle **800** may include a variety of subsystems (not all shown) configured to monitor and/or control vehicle functions such as ignition, propulsion, steering, braking, oil and tire pressure, control panel indicators, passenger compartment environmental parameters (e.g., temperature and air flow), and audio/video entertainment system settings. Such subsystems may range from complex (e.g., fuel injection as managed by the ECU **812**) to relatively simple (e.g., control of an interior "dome" light).

With additional reference to FIG. **9**, one embodiment of the VCE **100** of FIG. **1** is illustrated in the vehicle **800** of FIG. **8**. The vehicle **800** includes a VController **112** and VCE power source **114** that are coupled to one another and to a VSwitch **116**. The VSwitch **116** is coupled to a first VModule **118***a*, which is in turn coupled to a second VModule **118***b*. The VModules **118***a* and **118***b* are coupled to the tail light assemblies **816***a* and **816***b*, respectively. In the present example, each tail light assembly **816***a* and **816***b* includes multiple LEDs that are divided into a reverse light area, a brake light area, and a turn signal area. In some embodiments, the VModules **118***a* and **118***b* are incorporated into their respective tail light assemblies. In other embodiments, the VModules **118***a* and **118***b* are coupled to their respective tail lights but are separate components. The VController **112** is also coupled to a VModule **118***c*, which is in turn coupled to the ECM **812** via a proprietary cable.

In the present example, VModules in the VCE **100** are categorized into classes, including a passive switch class, a solenoid/actuator class, a motor class, a passive information display class, an interactive information display class, a passive data pass through class, a feedback data acquisition class, and a lighting control class. It is understood that these classes are for purposes of example and are not intended to be limiting. Furthermore, overlap may exist between certain classes and all or part of some classes may form a subset of another class.

The passive switch class includes subsystems and components such as simple on/off state switches or momentary contact switches that may be used for the door ajar sensors **820***a* and **820***b* or the passenger presence sensors **826***a* and **826***b*. This class may also include more complex multi-position passive switches used to control multiple functions or states, such might be used in windshield wiper controls to activate intermittent, slow, medium, and fast wiping intervals of the windshield wiper assemblies **836**.

The solenoid/actuator class includes subsystems and components used for electrically opening a door, trunk lid, or any other single action or process. The motor class includes subsystems and components used in operating windshield wipers (e.g., the windshield wiper assemblies **836**), hood/door opening mechanisms, movement of power seats or mirrors, and similar motorized operations.

The passive information display class includes subsystems and components that deliver visual display information for a user, including electric/electronic dashboard gauges in the gauge cluster **828**, active displays such as addressable matrix liquid crystal displays (LCDs), and organic light emitting diode (OLED) displays. The interactive information display class includes subsystems and components such as the interactive screen **834**, global positioning system (GPS) navigation devices, sound systems, active displays, and interactive starter switches that provide engine standby/start/stop control switching capabilities with a status display.

The passive data pass through class includes subsystems and components for performing data acquisition and pass-through, including passive displays. The feedback data acquisition class includes subsystems and components such as interactive displays, lighting control modules, and engine control modules. The lighting control class includes subsystems and components for the headlight assemblies **814***a* and **814***b*, daytime running lights, tail light assemblies **816***a* and **816***b*, and general interior and instrument panel lighting.

According to the preceding class list, VModules **118***a* and **118***b* of the present example are categorized as lighting control class modules. The VModule **118***c* may be categorized in the passive data pass or the feedback data acquisition class.

The VModule **118***c* is an example of a VModule that may interact with a legacy non-VEEDIMS enabled subsystem or component to provide at least a basic level of VEEDIMS functionality to the legacy non-VEEDIMS enabled subsystem or component. The VModule **118***c* receives CAN-bus data from the ECM **812** via a proprietary cable. The VModule **118***c* then converts the CAN-bus data into VNet data and sends the converted data over the VNet backbone. This makes the CAN-bus data available to the VCE **100** without the need to perform other conversions at VCE levels higher than the VModule **118***c*. In some embodiments, a VEEDIMS enabled ECM may be used in place of the ECM **812**, thereby allowing the ECM to be integrated seamlessly into the VCE **100**. A VEEDIMS enabled ECM may include the ability to cache engine start and run data until higher level control systems are ready to receive it. The caching technique may accommodate any latency, provide synchronization of time stamping, and allow higher level systems to be shut down for upgrading or maintenance without any data loss.

For purposes of example, the VModules **118***a* and **118***b* each include a circuit board having a Netburner that executes instructions so that each of the VModules forms a MAXI board as previously described. Each VModule **118***a* and **118***b* includes multiple power supplies needed to run the reverse lights of the reverse light area of the tail light assemblies **816***a* and **816***b*, and may include other power supplies to run the brake light and turn signal areas.

The VModules **118***a* and **118***b* can individually address the LEDs of each of the tail light assemblies **816***a* and **816***b* and may use fiber optic links or other means to receive feedback from the LEDs to identify brightness levels, etc. For example, when the vehicle **800** is started, the VModules **118***a* and **118***b* may perform a rapid test of each LED in the tail light assemblies **816***a* and **816***b* to ensure that the LEDs are working. This may be achieved using feedback obtained via a fiber optic link, thereby allowing the VModules **118***a* and **118***b* to measure a brightness level and color of each LED or of groups of LEDs. The color test may be accurate to a resolution of eighteen bits, which gives the VModules **118***a* and **118***b* a high degree of control over the light output of the tail light assemblies **816***a* and **816***b*. Using this information, the VModules **118***a* and **118***b* can control the output of the LEDs using, for example, a pulse width modulation (PWM) collective drive.

The feedback provided to the VModules **118***a* and **118***b* may be used for a variety of purposes other than testing. For example, the feedback may be used to control day and night lighting such as daytime running lights and may be used to adjust the intensity of the LEDs based on the ambient light level. In another example, the feedback may be used to provide active reflectors using the tail light assemblies **816***a* and **816***b*. To form active reflectors, the LEDs may remain off until the optic fibers detect light coming from an exterior source. One possible scenario in which this may occur is if the vehicle **800** has malfunctioned and is on the side of the road at night. Rather than leaving the hazard lights blinking and draining the battery, the fiber optics may detect headlights from other vehicles and, in response, may activate some or all of the LEDs to provide an active indication of the vehicle's presence. The LEDs may be flashed or otherwise manipulated to provide additional indicators.

The MAXI boards forming the VModules **118***a* and **118***b* may include one or more general purposes serial interfaces for purposes such as lighting control. For example, the MAXI boards may support DMX (used for lighting control by the entertainment industry) over Ethernet and other specialized digital control protocols. Other serial interfaces may be supported by the MAXI boards, including an RS232 compliant serial port.

In the present example, the tail light assemblies **816***a* and **816***b* each include a power supply (PS) board (not shown) positioned between the VCE power source **114** and the LEDs. The PS board may not be VEEDIMS enabled, but may be coupled to the VModules **118***a* and **118***b* via a uni-directional signal or a bi-directional signal. The PS boards are capable of setting a maximum current to the LEDs and the maximum current may be controlled by the corresponding VModules **118***a* and **118***b* via an addressable potentiometer positioned on the PS boards. The PS boards may also send PWM signals to the LEDs to control intensity and the PWM signals may be controlled by the VModules **118***a* and **118***b*. It is noted that some or all of the functions of the PS boards may be controlled locally so that the tail light assemblies **816***a* and **816***b* are able to operate without the VModules **118***a* and **118***b*.

Referring to FIG. **10**, in another embodiment, an environment **1000** illustrates a structure **1002** that contains the VCE **100** of FIG. **1**. In the present example, the structure **1002** is an above ground building that includes multiple floors **1004** and **1006** and one or more entry ways **1008** (e.g., a door). Landscaping, such as a flowerbed **1010**, may be positioned around the structure **1002**. The structure **1002** may be associated with multiple components and corresponding systems for monitoring and controlling the components. For example, the structure **1002** may be associated with an irrigation system **1012**, an environmental control system **1014**, a lighting system **1016**, an alarm system **1018**, and a security system **1020**. It is understood that each of the systems **1012**, **1014**, **1016**, **1018**, and **1020** may represent multiple systems or subsystems.

The irrigation system **1012** may be configured to control and monitor the provision of moisture to the flowerbed **1010** and other exterior landscaping and interior plant arrangements (not shown). The environmental control system **1014** may be configured to control and monitor heating and air conditioning facilities. The lighting system **1016** may be configured to control and monitor interior and exterior lighting of the structure **1002**, and may represent an interior lighting system and an exterior lighting system. The alarm system **1018** may represent a fire alarm system and a security alarm system. The alarm system **1018** may be configured to control and monitor safety components (e.g., fire alarms) within the structure **1002**, as well as security alarms (e.g., a burglar alarm on the door **1008** to indicate unauthorized entry or an alarm on an interior door to control access to a room or office suite). The security system **1020** may be configured to control and monitor cameras, motion sensors, and similar security devices, and may also control and monitor security alarms in some embodiments.

One or more VControllers **112** may be used to monitor and control the systems **1012**, **1014**, **1016**, **1018**, and **1020** via a VNet backbone that may or may not include power transfer capabilities. The VController **112** is coupled to multiple VModules **118***a*, **118***b*, and **118***c*. Although not shown, one or more VSwitches **116** may be positioned between the VController **112** and the VModules **118***a*, **118***b*, and **118***c*.

The VModule **118***a* is coupled to the irrigation system **1012**. The VModule **118***b* is coupled to the environmental control system **1014** and lighting system **1016**. The VModule **118***c* is coupled to the alarm system **1018** and security system **1020**. Each VModule **118***a*, **118***b*, and **118***c* may monitor, query, and control the coupled systems **1012**, **1014**, **1016**, **1018**, and **1020** as described above in previous embodiments.

In some embodiments, the VCE **100** may be tied to deeper systems, such as the main electric grid of the structure **1002**. In these cases, data obtained by the VCE **100** may be shared with other sources. For example, power grid data may be shared with the power company, which may in turn aggregate the information with other data for analysis. The analysis may be used to prevent problems including brownouts and blackouts and to track demand in a given area.

It should be understood that the drawings and detailed description herein are to be regarded in an illustrative rather than a restrictive manner, and are not intended to be limiting to the particular forms and examples disclosed. On the contrary, included are any further modifications, changes, rearrangements, substitutions, alternatives, design choices, and embodiments apparent to those of ordinary skill in the art, without departing from the spirit and scope hereof, as defined by the following claims. Thus, it is intended that the following claims be interpreted to embrace all such further modifications, changes, rearrangements, substitutions, alternatives, design choices, and embodiments.

What is claimed is:

1. A Virtual Electrical and Electronic Device Interface and Management System (VEEDIMS) support architecture comprising:

a vehicle layer having:

a module positioned in a vehicle and configured to couple to a device via an input/output (I/O) interface compatible with the device and configured to couple to a controller via a cable adapted to simultaneously carry bi-directional data and uni-directional power to the module, wherein the module has a first processor and a first memory containing a first instruction set executable by the first processor, the first instruction set including instructions for providing a HyperText Transfer Protocol (HTTP) server, and wherein the first memory further contains a documentation set containing a service history of the module and a bill of materials for at least one of the module and the device that is accessible via the HTTP server and both event driven and time series data captured from the device and the module during operation of the vehicle; and

the controller positioned in the vehicle and having a second processor and a second memory containing a second instruction set executable by the second processor, the second instruction set including instructions for receiving data from the module and storing the data in the second memory, wherein the data includes the event driven and time series data; and

a shop layer separate from the vehicle layer having:

a browser configured to communicate with the HTTP server to access the documentation set; and

an analysis tool configured to receive the event driven and time series data from the controller and analyze a performance of the vehicle compared to predefined optimal vehicle parameters using the event driven and time series data.

2. The VEEDIMS support architecture of claim **1** wherein the first instruction set further comprises instructions for a diagnostics component configured to obtain diagnostics data about the module and the device and to transfer the diagnostics data via at least one of the HTTP server and the cable.

3. The VEEDIMS support architecture of claim **1** wherein the first instruction set further comprises instructions for a configuration component configured to set operational parameters for at least one of the module and the device.

4. The VEEDIMS support architecture of claim **1** wherein the first instruction set further comprises instructions for a data acquisition component configured to acquire data about at least one of the module and the device.

5. The VEEDIMS support architecture of claim **4** wherein the data acquisition component includes an Embedded Component Historian Object (ECHO) coupled to an ECHO driver for sending the acquired data from the module to the controller via the cable.

6. The VEEDIMS support architecture of claim **1** wherein the first instruction set further comprises instructions for monitoring the device to create a device profile and sending the device profile to the controller.

7. A Virtual Electrical and Electronic Device Interface and Management System (VEEDIMS) support architecture comprising:

a vehicle layer having:

a plurality of modules positioned in a vehicle, wherein each module is configured to couple to at least one device via an input/output (I/O) interface compatible with the device and configured to couple to a controller via a cable adapted to simultaneously carry bi-directional data and uni-directional power to the module, and wherein each module has a first processor and a first memory containing a first instruction set executable by the first processor, the first instruction set including instructions for capturing and storing both event driven and time series data from the module and the device during operation of the vehicle; and

the controller positioned in the vehicle and having a second processor and a second memory containing a second instruction set executable by the second processor, the second instruction set including instructions for receiving data from each of the plurality of modules and storing the data in the second memory, wherein the data includes the event driven and time series data; and

a shop layer separate from the vehicle layer and having:

a communications component configured to obtain the data from at least one of the plurality of modules and the controller;

a server configured to store the obtained data; and

an analysis tool configured to review and analyze the event driven and time series data to correlate the event driven and time series data to a specific fault event and to view a status of vehicle layer systems during the interval of the specific fault event.

8. The VEEDIMS support architecture of claim **7** wherein the analysis tool is further configured to analyze the event driven and time series data from a point before a failure occurs to develop a picture of events that led to the failure.

9. The VEEDIMS support architecture of claim **7** wherein the event driven and time series data is filtered only for compression and exceptions to increase storage efficiency without losing resolution.

10. The VEEDIMS support architecture of claim **7** wherein the event driven and time series data is stored using a batch sub-system that stores pointers to a beginning and an end of specific parts of the event driven and time series data to allow for comparisons between similar events using overlay.

11. The VEEDIMS support architecture of claim **10** wherein the similar events include all engine start events, wherein the batch sub-system organizes the engine start events so the engine start events can be recalled and compared to develop a model of an optimal engine start.

12. The VEEDIMS support architecture of claim **11** wherein the engine start events are recalled and compared to predict a need for maintenance as parameters drift from the model of the optimal engine start.

13. The VEEDIMS support architecture of claim **7** wherein the analysis tool is further configured to execute a plurality of preventive maintenance functions by observing trends that move away from normal operational parameters based on the event driven and time series data.

14. The VEEDIMS support architecture of claim **7** wherein the analysis tool is further configured to identify fault conditions used to define predictive means for preventing future component failures based on the event driven and time series data.

15. The VEEDIMS support architecture of claim **7** wherein at least one of the first and second memories supports serial data storage of the event driven and time series data to enable time and excursion based fault analysis after a failure occurs.

16. The VEEDIMS support architecture of claim **7** wherein the shop layer further includes a configuration component configured to set parameters for at least one of the controller, the plurality of modules, and the devices coupled to the plurality of modules.

17. The VEEDIMS support architecture of claim **16** wherein the configuration component uses Extensible Markup Language (XML) configuration information.

18. The VEEDIMS support architecture of claim **7** further comprising an enterprise layer for fleet management having:

a communications component configured to obtain the data from the server in the shop layer;

a database configured to store at least a portion of the data from the server; and

a second analysis tool configured to retrieve the event driven and time series data from the data stored in the database for analysis.

19. The VEEDIMS support architecture of claim **7** wherein each of the plurality of modules includes a HyperText Transfer Protocol (HTTP) server, and wherein the first memory of each of the plurality of modules contains a documentation set containing a service history of the module and a bill of materials for at least one of the module and the device that is accessible via the HTTP server.

20. The VEEDIMS support architecture of claim **19** wherein the shop layer further includes a browser configured to communicate with the HTTP server to access the documentation set.

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